In the name of Allah, the Compassionate, the Merciful.

Praise is unto for Allah, the Lord of the Worlds,
the All-Compassionate, the All-Merciful,
the Master of the Day of Judgement.
They alone my worship
and to Thee alone we pray for help.

Show us the straight way,
the way of those whom Thou hast blessed
who have not incurred Thy wrath nor gone astray. [THE HOLY QURAN]
DEDICATION
To my mother, father and
uncles Mohamed and Ahmed
Mamoun.
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CHAPTER 1
INTRODUCTION

Banana, *Musa sap.* is one of the most important world crops. Only grapes exceed bananas in tonnage and they are mainly converted to wine whereas less than 2% of banana crop for international trade are processed (59). Bananas are of high nutritional value. It fits well with the recommendations of the Select Committee of the United States on Nutrition and Human Needs (6) for increased consumption of foods low in fats. It is a good source of vitamins, minerals and calories (78). It has been widely used as an element in nutrition for people suffering from intestinal disorders (76) and for obese and geriatric patients (56) due to its easy assimilation.

In Sudan, banana is the most widely consumed fruit due to taste and price reasons. Large quantities of good quality bananas are produced for local market (66), but no accurate records for production and areas under cultivation are available (25). The internal trade suffers from problems pertaining to transport and ripening methods. Poor transport on rough roads
leads to losses and deterioration of quality at ripening. Ripening is initiated in the traditional rooms by charcoal burning to make use of high temperature. Recently, some ripening-room owners used other ripening initiators such as ethylene, acetylene, and etanol.

This study was conducted to study the followings:

1- Ripening stage and varietal preference and effect of ripening temperature regimes on fruit acceptability.

2- Effect of some ripening reagents on banana ripening rate, fruit quality and fruit acceptability.

3- Effect of different ripening rooms commercially used in Khartoum area on fruit ripening rate, fruit quality and fruit acceptability.
fruits, this process takes place while the fruit is still attached to the plant. In others, it occurs after the fruit is detached from the plant (53). In commercial practices, bananas are never allowed to ripen on plant in order to avoid the splits of the peel (46). Bananas are picked green but mature and then ripened under controlled conditions. Commercial practices for banana ripening are selected to optimize the development of yellow color and residual shelf life after removing from the controlled conditions. This can be obtained by controlling temperature, relative humidity and ventilation.

2.1. Preharvest Factors

The preharvest factors affecting fruit ripening include the climatic factors and cultural practices. Of the climatic factors, temperature was found to have great effects on fruit ripening, e.g., warm days and cool nights are necessary for full development of
Color at ripe stage (70). Light also affects fruit ripening. The effect of light was found to be dependent upon duration, intensity and quality of light (70).

Fertilization increased the ripening rate (87) and resulted in fruits of good flavor (87). Chemical spraying also was found to improve the quality of the ripe fruits (70). Generally, any factor that affects plant growth invariably exerts its influence on the quality of harvested produce.

2.4.2. Maturity, Harvesting, and Transport of Bananas

Maturity is a physiological stage usually commences before growth ceases and includes different activities in different commodities (65). Maturity may be determined as follows: (a) visual means: color, size and fullness of fruits; (b) physical means: firmness and specific gravity; (c) chemical analysis: solids, acids, and starch content; (d) computation: days from bloom and heat units; and (e) physiological methods: respiration (70). For bananas, maturity is judged visually. The terminology and criteria for maturity vary, but the common practice is to designate
bananas as three quarters (fruits at about on half of their possible maximum full size, with clearly visible angles), full three quarters (fruits with less prominent angles), and full (fruits from which angles have virtually disappeared) (61).

Harvested fruits are transported from the plantation to a packing area either by a cable system, which prevents bunches contact with one another, or in padded carts. In the packing station, banana bunches are dehanded, cut into clusters, floated in water to remove latex from cut surfaces, and treated with an antioxidant and a post-harvest fungicide to prevent oxidation of post-packaging latex exudate and decay of fruits. Then clusters are packed in fiberboard boxes lined with polyethylene film to decrease transpiration. Banana boxes need to be transported under controlled conditions (102). For export, boxes are transported to the export markets in refrigerated ships at a temperature around 15°C (59).

Banana bunches are transported at varying maturities in bulk using 6-ton trucks lined with
banana leaves in Sudan. Handling and ripening losses were found to be about 40% (82). Transport bruises contributed 30% of the losses while 60% of them were due to mechanical damage. Ninety-five percent of fruits grown in Kasala and marketed in Khartoum were severely bruised during transport, while 30% of those grown in Wad Hamdi were bruised during transport to Khartoum.

2.1.3. Ripening Room Conditions

2.1.3.1. Temperature

Temperature directly or indirectly affects the ripening process. The activity of enzymes in fruits and vegetables declines at temperatures above 35°C. Many enzymes are still active at 35°C, but most are inactivated at 40°C (45). When produce is held at temperature above 35°C, metabolism becomes abnormal and results in breakdown of membrane integrity and often characterized by loss of pigments, and the tissue may develop a watery and translucent appearance (45). Such condition in banana is referred to as "boiled".
In mature green bananas, initiation of ripening and subsequent ethylene evolution, pulp softening, and sugar accumulation were accelerated with an increase of temperature up to 35°C, but degreening of peel was inhibited above 30°C and the evolution of volatilized compounds was suppressed at 35°C or above (105). Mature green bananas stored at 40°C showed no ethylene evolution and ripening signs (105). Bananas exposed to temperatures of 20°C, 30°C, 40°C, and 50°C exhibited a typical climacteric respiratory pattern (52). Fruits held at 20°C required 18 days to go through the ripening process with an acceptable appearance, while at 50°C they were unacceptable in only 1.5 days.

Not only abnormally high temperature produce damaging effects, but also abnormally low temperatures. Both green and ripe bananas are susceptible to chilling injury, but green fruit is slightly more susceptible. Chilling injury is mainly a peel injury. Sub-epidermal streaking, clear latex, loss of flavor, delayed ripening, khaki (yellowish brown) skin discoloration, slow conversion of starch to sugar, decrease in acetic acid level, watery dark green patches on the skin, and
brittleness of fingers are chilling symptoms of bananas (1, 7, 8, 9, 23, 46, 63, 66, 84, 98). In bananas, chilling may occur even in the normal range of holding temperature (14° - 22°C) depending on variety (97, 98), maturity grade (34, 81), and length of storage (19). Generally, bananas tolerate low temperature down to 13 - 14°C (38).

213.2. Relative Humidity (R.H.)

Relative humidity is the best known and perhaps the most widely used (and misused) term for expressing the water vapor condition of moist air. Relative humidity is defined as the ratio of the water vapor pressure in the air to the saturation vapor pressure at the same temperature, and is normally expressed as percent (25). It has physical, physiological and pathological effects on harvested crops (47, 48, 49). If it is too low, wilting and shrivelling are likely to occur in most fruits and vegetables, and if it is too high, it may favor the development of decay. Weight loss and shrinkage are related more to vapor pressure deficit (VPD) than to relative humidity (72, 75, 85, 83, 100). At
constant temperature, weight loss has a straight line positive correlation with relative humidity in the upper humidity range i.e. over 75% relative humidity (20), over 80% relative humidity (4), or over 85% relative humidity (85). Water stress increased respiration and ethylene production of preclimacteric bananas, but the height of the respiratory climacteric was reduced (47, 48). It is not clear whether relative humidity reduces chilling injury or just suppresses its symptoms. Relative humidity also affects flavor (5, 69, 92, 101) and wound healing (11, 29, 30, 39).

Relative humidity in ripening rooms is usually increased by the use of electric humidifiers and humidistats. In Salon, relative humidity is elevated by wetting the floor with water using saw dust and jute sacks or by the use of air coolers. The former has been found to increase decay in cold stores.
stalks of banana. Bruises and abrasions occurring during transport and unloading can readily become infected in unsanitary rooms. Regular cleaning and disinfection of the rooms can reduce new infections, maintain ripening rooms in good condition, and reduce the maintenance costs. Many non-toxic chemicals are recommended for cleaning and disinfection, e.g., sodium hypochloride.

2.1.3.5. Ripening Room in Sudan.

Ripening rooms usually have inadequate temperature control and humidity in not controlled. Different types of commercial ripening rooms are found in Khartoum area. The most widely used are the conventional ripening room in which charcoal is burned to initiate ripening, the semi-improved air-conditioned room and the mechanically refrigerated room (section 2.1.3.4). Sabir (90), who surveyed Khartoum ripening rooms, reported that temperatures in these rooms ranged between 22 - 35°C while relative humidity ranged between 66 - 87%. The high temperature recorded was inhibitory to ripening process and this was manifested by lack of flavor, green color,
and starchy state of the soft bananas available in retail markets\(^{(3)}\). The low humidity in ripening rooms caused desiccation of fruits and gave them a shrivelled appearance\(^{(94)}\). The actual losses of the ripening room owners may be below those estimated\(^{(82)}\) because of market acceptability to low quality bananas. However, the ripening room owners estimated their losses to be in the range of 15 - 30\(^{\circ}\)\(^{(3)}\).

### 2.1.4. Application of Ripening Reagents

#### 2.1.4.1. Ethylene.

Ethylene (\(\text{CH}_2 = \text{CH}_2\)) is physiologically active in trace amounts and is considered the natural ageing and ripening hormone\(^{(12, 21)}\). It increases respiratory activity, cell permeability and compartmentation and alters auxin metabolism and transport\(^{(75)}\).

The sensitivity of banana fruit to ethylene was found to be affected by physiological age of the fruit\(^{(12, 51, 71)}\), composition of gases\(^{(51)}\), partial pressure\(^{(24, 15)}\), and temperature\(^{(52)}\) in ripening room. The endogeneous ethylene concentration in banana fruits ranges between 0.06 - 0.2 ppm. Concentrations equal to or greater than this range are needed
to trigger ripening at normal ripening temperatures (18 - 22°C) (43). However, Liu (52) reported that at 40°C concentration of 0.015 - 0.05 ppm could trigger ripening. At a constant temperature and concentration, effect of ethylene on fruit ripening depends on maturity stage. Ethylene at 0.5 ppm has been found to take only one day to induce the climacteric rise of bananas at full maturity and 2.5 days for "light full three-quarter" mature fruits at temperature of 21°C. Low O₂ and high CO₂ atmosphere reduce the sensitivity of fruit to ethylene. This fact which applies to other fruits, was experimentally utilized in the controlled atmosphere and low pressure storage to extend the storage life of bananas (52).

Generally, ethylene applied to initiate banana fruit ripening at concentration of 1000 ppm for 24 hours at 20°C and 90 - 95% relative humidity (95).

2.1.4.2. Ethrel [2-chloroethyl phosphonic acid]

An important breakthrough in ethylene effects is the chemical synthesis of ethrel (40) which releases ethylene (106). In the presence of alkaline medium,
Ethylene evolves from ethrel with apparent release of chloride and phosphate (91). Ethrel is strongly acidic in aqueous solutions and is essentially stable below pH 4. The pH of cytoplasm in plants is generally above 4 (21, 28, 99). Many scientists duplicated the effects of ethylene by the use of an aqueous solution of ethrel (21, 28, 99). This suggests that the physiological effect of ethrel on plants is mainly due to its ability to release ethylene in plant tissue (21, 28, 99). Ethrel is commercially available and registered for use on a variety of crops and can be used to control developmental processes, or to induce ripening. It has no effect on fruit quality (26).

Ripening is promoted in many harvested fruits by dipping in 500 to 2000 ppm ethrel in aqueous solution for 30 sec. to 2 min or spraying fruits with the solution of the same concentrations (27, 28, 77, 78).

The disadvantage of ethrel as a ripening reagent is the application by dipping in or spraying with its aqueous solution which involves extra cost and enhances the spread of disease. In contrast to
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The disadvantage of ethrel as a ripening reagent is the application by dipping in or spraying with its aqueous solution which involves extra cost and enhances the spread of diseases. In contrast to
ethylene treatment, however, no especial arrange-
ments, like gas confinement, are required to ripen
fruits with ethrel, provided that temperatures are
within the range required to ripen the commodity.

2.1.4.3. Acetylene Gas.

Acetylene gas has the same biological effects
of ethylene gas on plants (10, 55). In some countries (78),
aacetylene gas is being used as a substitute for
ethylene to induce fruit ripening due to its avail-
ability, ease of preparation and less costs (108).
Acetylene can be applied from gas cylinder (56) or can
easily be generated from calcium carbide by adding
water (55, 56, 10). Acetylene is a reactive compound
and requires carefull handling. It is flammable and
will explode in air at 25 ml/litre (78). It reacts
with copper and produce more explosive products (41).

Its suitability as a ripening reagent depends on
its efficiency at concentrations well below the
explosive concentration with avoidance of using
copper materials in the ripening room.

Many investigations were carried out to
estimate the minimum effective concentration of
acetylene gas as a ripening agent. According to Young (205), it might be applied at 10,000 ppm to induce banana fruit ripening. Matan (56) suggested 2000 ppm to be sufficient when gas was supplied from cylinder and 20,000 ppm when generated from calcium carbide (one ounce CaC₂ in water generates 3-4 cubic feet acetylene). Pontesiero and Mendosa (67) and Seal and Chiang (92) stated that ethylene was 100 times more effective than acetylene.

No undesirable effects of acetylene on nutritional value of citrus when applied for degreening (2). Furthermore, acetylene was claimed to have the advantage of retarding shriveling and spoilage of fruits and so be of value to the producer and the consumer as well (15).

2.2. Compositional Changes During Banana Ripening

Many physicochemical changes occur during banana fruit ripening. The major changes are:

2.2.1. Carbohydrates

Carbohydrates are the major constituents in banana fruit pulp. Starch, which contributes 20-35% of the pulp weight of the fresh green fruit is
converted during ripening into free sugars (36% sucrose, 20% glucose, and 14% fructose)\(^{(61)}\). The enzymes or mechanism involved in this conversion are still unknown. Yang and \(\text{Ho}^{(107)}\) proposed that starch breakdown was catalyzed by phosphorlyase, but presented little evidence to support their proposal.

### 2.2.2. Pectic Substances and Cellulose and Hemicellulose

During ripening, the insoluble protease is converted into soluble pectins resulting in softening of the fruit\(^{(46)}\). Enzymes involved in pectin conversion are pectin methyl esterase (PME) and pectinase\(^{(61)}\). Cellulose and hemicellulose decreased during ripening from 2-3% to 1% for cellulose and from 3-10% to 5% for hemicellulose\(^{(61)}\).

### 2.2.3. Pigments

Change in peel color from green to yellow occurs during ripening and serves as a rough guide to the stage of ripeness. Chlorophyll degradation (loss of green color) occurs due to the activity of chlorophyllose enzyme which depends on temperature. Yellowing begins at or shortly after the climacteric
peak and the fruit becomes fully yellow within 3–7 days at normal ripening temperature (61).

2.2.4. Phenolic Compounds

With exception of dopamine (3, 4-dihydroxy phenylethyl amine), the primary substrate for browning reaction, phenolic substances of banana fruit received little attention. Dopamine was reported by Walske et al. (96) to occur in high concentration (900 ug/g fr. wt.) in banana peel and in low concentration (6 ug/g fr. wt.) in banana pulp. Certain tannins are believed to be responsible for the sensation of astringency, via cross-linking of proteins in the mouth (95). Total phenolic compounds of banana fruit decreased during ripening (61).

2.2.5. Acidity

The pH of banana pulp falls during ripening from 5.4 (± 0.4) in preclimacteric to about 4.5 (± 0.3) in postclimacteric pulp (61). Malic, citric, oxalic, and tartaric acids increase during ripening (61).
2.2.6. Vitamins

Little research has been done with vitamins in bananas. Mc Cance and Widdowson (56) tabulated data on vitamin content. Ascorbic acid has been found to increase slightly in the pulp just after climacteric(56).

2.2.7. Appearance of Flavor and Aroma.

Increase in the synthesis of banana volatile substances commences late in the climacteric (about 24 hours). The volatile constituents are complex, about 350 have been separated. Esters make the main contribution to the climacteric banana aroma. The major volatile constituents have been classified according to their general sensory impression: banana-like (e.g. amyl acetate), fruity (e.g. butyl acetate) and green woody or musty (e.g. hexyl alcohol, amyl alcohol)(56).

2.3. Sensory Evaluation

When the quality of food is assessed by means of human sensory organs, the evaluation is said to be sensory or subjective. The sensory evaluation is
called upon to provide information on whether differences exist between or within treatments, to determine the intensity of a sensory property or the degree difference, to correlate an objective measurement with subjective assessment, and inappropriately, to establish degree of liking.\(62\).

The highly subjective nature of the human evaluation of food quality discourages many investigators, but as long as the ultimate evaluation of food is made by human senses, sensory testing will be an available part of product development and quality control.

Scoring is the oldest measure for such tests and is most frequently used due to its diversity, simplicity, and ease of statistical analysis.\(62, 43\). It consists of evaluating on a pre-established numerical basis, single or multiple factors that influence quality. When used in commercial quality control for official grading purposes, the score is usually intended as a criterion of the overall quality of the product.\(62\). When used in research, the score usually indicates the intensity of a single
quality characteristic, but if several properties are to be evaluated, the scores of each are usually recorded and interpreted independently (62).

Hedonic scaling is frequently used at the consumer level since it reflects the attitudes of people towards certain foods under a given set of conditions. Hedonic relates to the psychological of pleasant and unpleasant states of consciousness. In hedonic scaling, effective responses, i.e., psychological states of like and dislike, are measured on a rating scale. When measuring the food quality, a 10-point structure hedonic scale ranging in descriptive terms, which are converted to integers from 1 to 10 for statistical analysis, is frequently used (62).

The important factors for consumers to determine the quality of food are (45) appearance "including color, size, and shape", condition (that is to say presence and absence of defects), texture, flavor, and nutritional value. The first four factors are sensory attributes. Kramer (44) and Charley (18) illustrated the overlapping of the sensory factors.
and gave more information about this aspect. In addition to these factors, the consumer himself affects fruit acceptability. Szczepaniak and Kley reported that the people of high educational, social and economic status and those exposed to a greater range of foods were generally more aware about food texture than less cosmopolitan people. The same authors found that women appeared to be more texture-conscious than men and in this respect were less influenced by their technical background. Furthermore, certain psychological factors have been found to contribute to the acceptability. Pleasant associations increase the likelihood that the food will be accepted and unpleasant associations increase the probability that the food will be rejected. Tradition also plays a major role in food acceptability. Generally, eastern people like sweet more than western people. A recent market research on the American consumer preference to "Dwarf Cavendish" bananas, stated that half ripe stage was more preferred to green and fully ripe stages.
Nutrition is probably the least important consideration in deciding whether the consumer purchases a commodity, since most essential nutrients can neither be seen nor tasted, e.g. vitamin C is the most important nutrient. However, few people would decide to buy a particular piece of fruit because it had more vitamin C than the other types of fruits.
CHAPTER 3
CHAPTER 3
MATERIALS AND METHODS

3.1. Source of Bananas

Bananas for all experiments were obtained from a private orchard in Khartoum North except in experiment 3.1.1 for which bananas were obtained from a private orchard in Al-Sarabi area, Khartoum North. Fruits were harvested at "full three quarters" mature green stage (a maturity stage described by Palmer(56)). Fruits were dehooned in the field and washed in the ripening room with tap water to remove latex and dust.

3.2. Organoleptic Tests and Hedonic Scale.

Different stages of ripeness preference, varietal preference and effect of different ripening temperature regimes, ripening stages and ripening conditions on fruit acceptability were studied. Twenty panelists were participated in each test. They were asked to taste the fruit samples and give their evaluations for sweetness, aroma, softness, and general eating quality of the samples according to a 5-point structured hedonic scale given to them.
The scale ranged in descriptive terms from "very starchy, inedible" to "very sweet" for sweetness; from "non" to "very strong" for acidity; from "too firm, inedible" to "juicy" for softness; and from "inedible" to "excellent" for general eating quality along a 9-point scale (Appendix I). Fruits were presented to consumers peeled and unpeeled to study the effect of skin color on consumer preference. Scores were analyzed using the variance method (45, 62). The split plot design was applied. Presence and absence of fruit peel were the two main plot treatments. Subplot treatments were the ripening stages, the varieties, the ripening temperature regimes, the ripening reagents or the ripening room conditions in experiments 3.4.1, 3.4.2, 3.4.3, 3.5.2 and 3.6.2, respectively.

3.3. Ripening Rate Parameter.

Color change was the parameter followed to study the ripening rate in all experiments according to Chiquita Color Chart (Appendix II).
3.4. Sudanese Consumer Preference

These experiments were conducted to study the ripening stage and varietal preference of Sudanese consumers. The experiments also investigated the effect of ripening and holding temperatures on fruit acceptability.

3.4.1. Stage of Ripeness Preference

This experiment was conducted to show which stage of ripeness is most preferred by Sudanese consumers.

Two bunches of 'Dwarf Cavendish' bananas were used. Five hands from each bunch were divided into fingers. Two fingers were taken from each hand to make six 20-finger groups. The six groups were treated with 1000 ppm ethylene to initiate ripening at 24-hour intervals to obtain six different stages of ripeness on the day the organoleptic test to be held. Fruits were ripened at 20% and 85% relative humidity in Food Research Centre's cold store.
Six stages of ripeness (from 5 to 8 according to Chiquita Color Chart) were tested. Fruits stored for 24 hours after stage 7 were considered to be as stage 8.

3.4.2. Varietal Preference

A bunch of "Dwarf cavendish" banana and another of "Giant cavendish" were used in this experiment. The Giant bunch was divided into three parts from proximal to distal ends. Fruits of the middle part were equal in size to those in the proximal end of Dwarf bunch. The two were compared to each others to eliminate the effect of fruit size on consumer preference.

Fruits from proximal hands of each bunch were also compared to each other in a separate panel test to include the size effect. The outer and inner lengths of banana fingers were 20 and 12.5 cm in Giant and 15 and 10 cm in Dwarf type.
3.4.3. Effect of Ripening and Holding Temperatures on Fruit Acceptability

Three bunches of "Dwarf cavendish" bananas were used. Four proximal hands from each bunch were divided into fingers. Fruits were grouped into five groups and ripened under the following temperature regimes:

1- At 30-40°C for 2 days by burning charcoal to initiate ripening (conventional method).

2- At room temperature (26-29°C) for 8 days.

3- At 20°C and 90-95% relative humidity upto stage 7 (advanced method).

4- At 20°C and 90-95% relative humidity upto stage 4 then transferred to room temperature upto stage 7.

5- At 20°C and 90-95% relative humidity upto stage 4 then at 37°C for 24 hours.

The last two treatments were included to simulate retail conditions and to test fruit acceptability at these conditions.
3.5. Effect of Ripening Reagents on Ripening Rate, Fruit Quality, and Fruit Acceptability.

3.5.1. Ripening Rate.

3.5.1.1. Effect of Ethylene, Acetylene, and Ethrel.

This experiment was conducted to test the effect of ethylene, acetylene and ethrel at 5 different concentrations of each on banana fruit ripening rate. Four hands from a bunch of "Dwarf cavendish" bananas were used. Fingers from each hand were replicated among 13 treatments in a randomised complete block design. Fruits in each replicate were treated with ethylene at 1, 10, 100 and 1000 ppm; acetylene at 10, 100, 1000 and 10,000 ppm; ethrel at 200, 400, 800 and 1600 ppm; and one was left untreated as control.

Fruits were placed in 4-litres empty powdered milk cans. A 5-cm metallic tube (4 cm in diameter) was sealed through the cover of each can. A 10-cm plastic tube was joined with one side to the upper part of the metallic tube and tightly sealed in the other side to facilitate the application of gases inside the cans. The free space in each can was measured after measuring the sample volume using
the displacing method. Ethylene and acetylene gases were injected by plastic syringes. Twenty four hours after application the cans were opened. Ethrel treatments were applied by dipping the fruits for 5 minutes in ethrel aqueous solutions and then air dried to remove the excess water. Ethrel-treated fruits and untreated ones were also kept in closed powdered milk cans and opened 24 hours later.

Fruits were ripened in University of Khartoum cold store at 20°C and 90-95% relative humidity. Color change was followed daily as a ripening rate parameter.

3.5.1.2. Effect of Ethrel Concentration on Banana Ripening Rate.

This experiment was conducted to study the effect of ethrel at concentrations less than 200 ppm on banana ripening rate. A bunch of "Dwarf Cavendish" bananas was used. The experiment was designed as previously described (section 3.5.1.1). Ethrel was applied at 0, 30, 60, 90, 120, 150 and 200 ppm as a dip for 5 minutes. Color change was followed daily as a parameter for ripening rate.
Fruits in each block were treated with ethylene at 20 ppm, acetylene at 1000 ppm and ethrel at 200 ppm or left untreated as control. Fruits were ripened as described in section 3.5.1.1.

Physical and chemical parameters were measured daily till the third day and every other day till the seventh day. Color change was followed according to Chiquita Color Chart (Appendix II). Fruit firmness was measured in peeled fruits using Magnus and Taylor pressure tester (D. B. Eklauf Mfg. Company). Total soluble solids were measured using a hand refractometer (Bellingham and Stanley Ltd., London).

Total sugars, total phenolics and pH were determined in the pulp tissue extract which was prepared as follows:

Thirty grams peeled fruit were homogenized in 100 ml distilled water for 1 minute. The homogenate was centrifuged at 6000 xg for 20 minutes in a SRL bench centrifuge. The supernatant was filtered through Whatman No. 1 filter paper. The volume of extract was measured.
3.5.1.3. Effect of Method of Application of Ethrel on Banana Ripening Rate.

This experiment was conducted to compare two methods of ethrel application on banana ripening. A bunch of "Dwarf cavendish" bananas was used. Fruits were dehanded and divided into seven 4-finger groups. Three groups were treated with 200 ppm ethrel by dipping fruits in ethrel aqueous solution for 1, 3 and 5 minutes. One group was dipped in distilled water. Two groups were sprayed on one side to dripping point with 200 ppm ethrel, and with distilled water, respectively. The last group was left untreated. Fruits were ripened at 20°C and 90-95% relative humidity. The experiment was designed as in section 3.5.1.1. Color change was recorded daily as a parameter for the ripening rate.

3.5.2. Fruit Quality

This experiment was conducted to study the effect of ethylene, acetylene, and ethrel on banana fruit quality. A bunch of "Dwarf cavendish" bananas was used. Three hands were utilized and considered as three replicates in a randomized complete block design.
The pH was measured using pH meter (model 73, PYe and Comp.). Total sugars content was measured by the Anthrone method (Appendix III). Total phenolics content was measured using Folin reagent (Appendix IV).

### 3.5.3. Fruit Acceptability

This experiment was conducted to study the effect of ethylene, acetylene, and ethyl alcohol on banana fruit acceptability. Fruits for this experiment were taken from the same bunch of the previous experiment and treated in similar way as described earlier (section 3.5.2). The organoleptic test was held 6 days after treatment. The test was conducted as described in section 3.2.

### 3.6. Effect of Ripening Conditions on Ripening Rate, Fruit Quality, and Fruit Acceptability

This part of study was conducted to compare three different methods of banana fruit ripening practiced commercially in Khartoum area. This include: the traditional charcoal method, semi-improved air conditioned ripening rooms, and improved mechanically refrigerated ripening room method.
In the traditional charcoal method, 4-5 tons of banana bunches were stacked in a 4 x 3 x 3.5 m room. Charcoal (about 1 kg) is burned and kept into the room which is closed for 24 hours in summer, while in winter another kilogram of charcoal is burned for another 24 hours. Bananas were removed from the room in bunches to semi-shaded backyard. Fruits were damaged and stacked over each other to about 0.2 - 0.3 box in each bag and covered with newspapers for 24 hours in summer and 48 hours in winter. After that fruits became soft green and ready for sale.

The semi-improved air conditioned ripening room was 4 x 4 x 3.5 m. The walls and door were insulated with 5 cm thick polyurethane sheets. The room was equipped with two wind-type air conditioners. Relative humidity inside the room was uncontrolled. The floor was wetted with water to elevate the relative humidity in the room. Bunches were stacked as bunches in the room and 24 hours later they were debanded and put on 50 - 60 cm wide shelves. No ripening reagent was applied.
The mechanically refrigerated ripening room was constructed with double walls sandwiched with 5-cm thick polyurethane sheets and door was insulated. It was equipped with a refrigeration unit and temperature was controlled automatically by a thermostat. It was fitted with a dial wall thermometer with extended probe to the inside of the room to check temperature changes. Fruits were dehanded and put on 50 - 60 cm wide shelves. Ethrel was applied at 200 ppm to initiate ripening.

3.6.1. Effect of Ripening Conditions on Fruit Ripening Rate.

Three "Dwarf Cavendish" banana bunches were used. Each bunch was ripened under the conditions of one of the three ripening rooms described before (section 3.5). The temperature and relative humidity were recorded during the ripening period under the three ripening conditions using a thermohygrograph (Karl Kolb, Scientific Technical Supplies, Type 252). This experiment was repeated to study the effect of dehandering on ripening rate. Bananas were ripened as bunches.
Fresh weight, color score, fruit firmness, and total soluble solids of the fruits were determined initially, after 4 days and then after removal from the ripening rooms in the experiment where bunches were used. In the experiment where bunches were used parameters were recorded daily in the three ripening rooms.

3.6.2. Effect of Ripening Conditions on Fruit Quality.

This experiment was conducted to study banana fruit quality under the condition of the three ripening rooms described in section 3.6. Fruits at 1.03 kg/m² pulp firmness (using Magnus and Taylor pressure tester) ripened under the conditions of the three ripening rooms were used. Duration of ripening in each room was recorded. Total soluble solids, pH, total sugars and total phenolics were determined as described in section (3.5.2.). Ascorbic acid content was determined by the titration method (Appendix V). Randomized complete block design was used for statistical analysis.
Fruit samples ripened under the conditions of the three ripening rooms were used in organoleptic test as described in section 3.2.
CHAPTER 4
RESULTS

4.1 Sudanese Consumer Preference
4.1.1 Preference for Different Stages of Ripeness

For sweetness (Fig. 1.6) panelists considered bananas in stage 3 to be starchy but edible with mean scores of 1.5 when peeled and 1.25 when unpeeled. Sweetness of fruit at stage 4 was considered intermediate to starchy with a mean score of 2.5 for peeled and unpeeled fruits. Panelists considered stage 5 to be intermediate to sweet with a mean score of 3.5 for peeled and 3.5 for unpeeled fruit. Stage 6, 7, and 8 were considered as sweet to very sweet with mean score of 4.3, 4.15, and 4.1 when peeled and 4.35, 4.25 and 4.25 when unpeeled, respectively.

Significant differences were found between means of stages 3, 4 and 5. Differences between the other stages and stage 3 were not significant. No significant difference was found between peeled and unpeeled fruits in all stages (Fig. 1.6).

Stage 3 was considered poor in aroma with a mean score of 1.25 when peeled and 1.45 when unpeeled. Stage 4 was considered to have a poor to intermediate
aroma having a mean score of 2.5 when peeled and 2.35 when unpeeled. An intermediate to strong aroma was estimated for stage 5 with a mean score of 3.25 when peeled and 3.05 when unpeeled. Stage 6 had strong aroma according to consumers having a mean score of 3.95 when peeled and 3.9 when unpeeled. Stage 7 and 8 were considered to have an intermediate to strong aroma when peeled with a mean score of 3.85 and 3.65 and to have a strong aroma when unpeeled having a mean score of 4.05 and 4.45, respectively (Fig. 1.b). Differences between stage 3, 4, 5 and 6 were significant while difference between stage 6, 7 and 8 were not using duncan multiple range.

For softness (Fig. 1.c) panelists considered stage 3 to be firm (inedible) to firm (but edible) having a mean score of 1.5 when peeled and 1.35 when unpeeled. Stage 4 was considered to be firm (but edible) to soft. Scores given for this stage were 2.2 when peeled and 2.5 when unpeeled. Stage 5 was considered to be soft having a mean score of 3.15 when peeled and 2.9 when unpeeled. Stage 6, 7 and 8 were considered to be soft to very soft (but edible)
having a mean score of 3.1, 3.3 and 3.9 when peeled and 3.3, 3.35 and 5.5 when unpeeled, respectively. Significant differences were found between stage 3, 4 and 5, but no significant difference was found between stage 5 and 6. Difference between stage 5 and 7 was significant, but between stage 6, 7 and 8 were not (Fig. 1.a).

Stage 5 was considered as definitely poor to poor in eating quality with a mean score of 2.75 when peeled and 2.2 when unpeeled. Stage 4 was considered to be slightly poor to intermediate in quality with a mean score of 4.7 when peeled and to be intermediate to fairly good when unpeeled with a mean score of 5.2. Consumers considered Stage 5 as fairly good to good with a mean score of 6.6 when peeled and 5.3 when unpeeled. Quality of Stage 6 and 7 was considered as good to very good with mean scores of 7.6 and 7.5 when peeled and 7.9 and 8.0 when unpeeled respectively. Stage 8 was considered as good to very good in quality when peeled with a mean score of 7.5 and to be very good to excellent with mean score of 8.25 when unpeeled (Fig. 1.c). Differences between stage 5, 4 and 5 were
Fig. 1. a) sweetness

b) aroma

c) softness

d) eating quality

Ripening stages
significant, but differences between stage 8, 9 and 10 were not. No significant difference was found between peeled and unpeeled fruits.

4.1.2. Varietal Preference

For sweetness (Fig. 2.a) panelists gave a mean score of 3.5 and 3.75 for peeled and 3.4 and 3.65 for unpeeled Giant and Dwarf bananas, respectively. Significant difference was found between the two types (Fig. 2.a).

Giant cavendish bananas scored 3.0 when peeled and 3.15 when unpeeled, while Dwarf bananas scored 3.15 when peeled and 3.4 when unpeeled for aroma (Fig. 2.b).

Mean scores of 2.95 and 3.05 were given for peeled fruits and 2.0 and 2.95 for unpeeled fruits of Giant and Dwarf types, respectively, for softness (Fig. 2.c).

For general eating quality (Fig. 2.d) panelists gave a mean score of 6.0 for peeled and 6.9 for unpeeled Giant bananas and 6.4 for peeled and 6.8 for unpeeled Dwarf bananas. Statistically,
Fig. 1: Mean scores given by 20 panelists for (a) sweetness, (b) aroma, (c) softness and (d) general eating quality of peeled (P) and unpeeled (E) bananas at different ripening stages (5 to 8). Columns headed by the same letters show no significant differences.
the differences between the Giant and Dwarf types were not significant in the last three parameters (aroma, softness and general eating quality). Unpeeled fruits got significantly higher scores than did peeled fruits.

In the fruit size preference test, panelists gave a mean score of 4.25 and 3.6 to peeled fruits and 4.35 and 3.65 to unpeeled fruits for Giant and Dwarf types, respectively, for sweetness (Fig. 5.a).

Mean scores of 3.45 when peeled and 4.2 and 4.15 when unpeeled were given to aroma of Giant and Dwarf types, respectively (Fig. 5.b). The mean scores given for softness of Giant were 3.2 when peeled and 3.3 when unpeeled. Those given for Dwarf were 3.25 when peeled and 3.3 when unpeeled (Fig. 5.c).

For general eating quality (Fig. 5.d), Giant fruits were given a mean score of 8.25 when peeled and 8.6 when unpeeled. Dwarf fruits were given a mean score of 6.9 when peeled and 7.4 when unpeeled (Fig. 5.e). Significant differences were found between means of the two varieties in all parameters.
Fig. 2.

a) Sweetness

b) Aroma

- LSD(1%)
- Peeled fruit
- Unpeeled fruit

c) Softness

d) Eating quality

- Giant
- Dwarf (Varieties)
- Giant
- Dwarf
Fig. 2: Mean scores given by 20 panelists for (a) sweetness, (b) aroma, (c) softness and (d) general eating quality for peeled (P) and unpeeled (U) Giant and Dwarf cavendish bananas.
Fig. 3: Mean scores given by 20 panelists for (a) sweetness, (b) aroma, (c) softness and (d) general eating quality of Giant (L) and Dwarf (S) Cavendish banana fruits different in size. Vertical bars (1) show the L.d.9. (1#).
tasted except softness. Unpeeled fruits got significantly higher scores than did peeled ones.

4.1.3. Effect of Ripening and Holding Temperatures on Fruit Acceptability,

For sweetness (Fig. 4.3) panelists gave bananas ripened by the charcoal method a mean score of 2.7 when peeled and 1.8 when unpeeled. Bananas ripened at room temperature (26 - 29°C) for 8 days were given a mean score of 3.9 and 3.25 when peeled and unpeeled, respectively. Those ripened continuously at 20°C and 90 - 95% R.H. were given a mean score of 3.6 and 3.0 when peeled and unpeeled, respectively. Panelists gave a mean score of 4.0 for peeled and 4.25 for unpeeled bananas ripened at 20°C to stage 4 and then transferred to room temperature (26 - 29°C) to stage 7. Bananas ripened at 20°C to stage 4 and held at 27°C for 24 hours (reached color stage 5) were given a mean score of 4.25 when peeled and 4.35 when unpeeled. No significant difference was found between fruits ripened at 20°C up to stage 4 and then transferred to higher temperatures,
but the differences between these fruits and those ripened at other temperature regimes were significant (Fig. 4.a).

Mean scores of 2.4 and 2.1 were given for aroma of bananas ripened by the charcoal method when peeled and unpeeled, respectively. Those ripened at room temperature for 8 days were given a mean score of 3.6 and 3.05 when peeled and unpeeled, respectively. Bananas ripened continuously at 20°C were given a mean score of 3.5 for peeled and 3.6 for unpeeled. Those ripened at 20°C to stage 4 and then transferred to room temperature (26 - 29°C) to stage 7 were given a mean of 3.3 when peeled and 3.45 when unpeeled. Bananas ripened at 20°C to stage 4 and held at 37°C for 24 hours were given mean scores of 3.25 and 3.6 for peeled and unpeeled, respectively (Fig. 4.b). No significant difference was found between them and those ripened at higher temperature were significant.

Test for softness (Fig. 4.c) gave those ripened by the charcoal method a mean score of 2.5 when peeled and 2.15 when unpeeled. Panelists gave
bananas ripened at room temperature for 8 days mean scores of 3.8 and 3.7 when peeled and unpeeled respectively. Bananas ripened continuously at 20°C to stage 7 scored 3.1 for peeled and 3.05 for unpeeled fruits. Those ripened at 20°C and then transferred to room temperature (26 - 29°C) were given a mean score of 3.15 when peeled and 3.1 when unpeeled. Mean scores of 3.6 and 3.4 were given to bananas ripened at 20°C to stage 4 and held for 24 hours at 37°C when peeled and unpeeled, respectively. No significant difference was found between fruits ripened at room temperature for 8 days and those transferred from 20°C to 37°C. Difference between the three groups ripened at 20°C was not significant, but that between the fruits ripened by the charcoal method and the other groups was significant.

For general eating quality (Fig. 4a) bananas ripened at high temperature (charcoal method) were given a mean score of 3.15 for peeled and 3.6 for unpooled. Those ripened at room temperature for 8 days scored 5.5 and 5.4 for peeled and unpeeled respectively. Bananas ripened continuously at 20°C
Fig. 4: Mean scores given by 20 panelists for (a) sweetness, (b) aroma, (c) softness and (d) general eating quality of peeled [■] and unpeeled [□] bananas ripened at (1) high temperature by charcoal method, (2) room temperature for 8 days, (3) 20°C upto stage 7, (4) 20°C upto stage 4 and then at room temperature upto stage 7, and (5) 20°C upto stage 4 and then at 37°C for 24 hours. Columns headed by the same letters show no significant difference.
to stage 7 were given a mean score of 7.0 when peeled and 7.4 when unpeeled. Panelists gave those ripened at 20°C to stage 4 and transferred to room temperature to stage 7 a mean score of 7.1 when peeled and 7.4 when unpeeled, while those ripened at 20°C and held for 24 hours at 37°C were given mean scores of 6.3 and 7.0 when peeled and unpeeled, respectively. No significant differences were found between fruits ripened at 20°C, but there was significant difference between them and the other groups. No significance between peeled and unpeeled fruits, but there is an interaction between color effect and temperature effect.

4.2. Effect of Different Ripening Reagents on Ripening Rate and Fruit Quality and Acceptability.

4.2.1. Ripening Rate.

4.2.1.1. Effect of Ethylene, Acetylene, and Ethrel on Banana Ripening Rate.

Untreated bananas remained firm and green (color index No. 2) for all days and reached color
Fig. 5: Color scores of bananas treated with (A) ethylene at 1 (Δ), 10 (●), 200 (○) and 1000 (●) ppm; (B) acetylene at 10 (Δ), 100 (●), 1000 (○) and 10000 (●) ppm and (C) ethrel at 200 (Δ), 400 (△), 800 (○) and 1600 (●) ppm compared to untreated fruits (— —). Concentrations of the same letters show no significant difference.
index No. 4 (ripening stage at which bananas are removed from ripening rooms to retailers) in 3.75 days. Ethylene triggered ripening at all concentrations used. Bananas treated with 1, 10, 100 and 1000 ppm ethylene reached color index No. 4 in 3.75, 3.25, 3.0 and 2.75 days, respectively. Significant differences were found between 100-fold increases in ethylene concentration (Fig. 5.a).

Acetylene also triggered ripening at all concentrations applied. Fruits treated with 10 and 100 ppm reached color index No. 4 similarly in 3.75 days. Those treated with 1000 and 10,000 ppm reached that stage in 3 days with significant difference (Fig. 5.b).

Ethrel-treated bananas at the four concentrations used were triggered similarly and reached color index No. 4 in 3 days at the same time (Fig. 5.c).

4.2.1.2. Effect of Ethrel Concentration on Banana Ripening Rate.

Color score of bananas treated with 0, 20, 40, 80, 120, 160 and 200 ppm ethrel is shown in
Fig. 6: Color score of bananas treated with 20 (□), 40 (■), 80 (▲), 160 (▲), and 200 (●) ppm ethrel compared with untreated bananas (—). Treated fruits were dipped in ethrel solution for 5 min. Horizontal bar (---) shows the L.S.D. (5%).
Figure 6. Untreated bananas and those treated with water (0.0 ppm ethrel) remained firm and green (color index 2) for 11 days and reached color index No. 4 after 15 days. Ethrel at all concentrations applied triggered ripening. Fruits treated with 20 and 40 ppm reached color stage 4 in 10.75 days. Those treated with 80, 120, 160 and 200 ppm reached that stage in 10.25, 9.0, 4.75 and 4 days, respectively. No significant difference was found between the ripening rate of the fruits treated with 100 and 200 ppm, but there was significant differences between them and the rest of the treatments. No significant differences were found between the untreated fruits and those treated with ethrel upto 120 ppm.

4.2.1.3. Effect of Ethrel Method of Application on Banana Ripening Rate

Untreated fruits and those treated with water by dipping or spraying remained firm and green for 11 days and reached color index No. 4 after 14 days. Fruits dipped in ethrel solution for 1, 5, and 5 min. reached color index No. 4 in 5.5, 3.0 and 3.0 days, respectively. Those sprayed with 200 ppm
Fig. 7: Color score of bananas treated with 200 ppm ethanal solution by dipping for 1 (▲), 3 (●) and 5 (○) min. or by spraying fruits on one side to dripping point (△) compared to untreated fruits (■) or fruits treated with distilled water by dipping (■) or spraying (.....). Fruits were ripened at 20°C and 90 - 95% R.H. Horizontal bar (---) shows the L.S.D. (5%).
for different periods, the significant differences were found between spraying and dipping for 3 and 5 min.

4.2.2. Fruit Quality of Bananas Ripened By Different Ripening Reagents.

Pulp firmness and total soluble solids (T.S.S) changes during ripening of bananas treated with 10 ppm ethylene, 1000 ppm, and 200 ppm ethanol at 20% and 90 - 95% R.H. are shown in Figure 3. Untreated fruits remained at the initial firmness (7.3 kg/cm²) and the initial T.S.S (3.75%) for the 7-day ripening period. Fruit firmness progressively declined from 7.3 kg/cm² initially to 1.95, 1.92 and 1.96 kg/cm² in the seventh day in fruits treated with 10 ppm ethylene, 1000 ppm acetylene, and 200 ppm ethanol, respectively. Total soluble solids progressively increased from 3.75% in the initial day to 21.66% in ethylene-treated fruits and 21% in acetylene - treated and ethanol - treated fruits. Difference was not significant.
The initial total sugar content of treated bananas (10.5 - 11.3 mg/g pulp) increased about 20 folds in seven days while the untreated fruits remained at the initial sugar content (Fig. 9). No significant differences were found between ethylene, acetylene, and ethrel-treated fruits at the concentration used.

Total phenolic content decreased from 181.6 - 186 mg/g pulp to 102, 72.5, 68.6 and 72.3 mg/g pulp in untreated fruits and fruits treated with 10 ppm ethylene, 1000 ppm acetylene, and 200 ppm ethrel, respectively (Fig. 10). No significant difference was found among all treated fruits, but difference between treated and untreated fruits was significant.

The pH of the pulp decreased slightly from 5.24 to 5.1 in the untreated fruits while in treated fruits it decreased to 4.55 (Fig. 11). Difference was not significant between treated fruits, but significant differences were found between treated and untreated fruits.
The initial total sugar content of treated bananas (10.5 - 11.3 mg/g pulp) increased about 20 folds in seven days while the untreated fruits remained at the initial sugar content (Fig. 9). No significant differences were found between ethylene, acetylene, and ethanol-treated fruits at the concentration used.

Total phenolic content decreased from 181.6 - 235 mg/g pulp to 102, 72.3, 68.6 and 72.3 mg/g pulp in untreated fruits and fruits treated with 10 ppm ethylene, 1000 ppm acetylene, and 200 ppm ethanol, respectively (Fig. 10). No significant difference was found among all treated fruits, but difference between treated and untreated fruits was significant.

The pH of the pulp decreased slightly from 5.34 to 5.1 in the untreated fruits while in treated fruits it decreased to 4.35 (Fig. 11). Difference was not significant between treated fruits, but significant differences were found between treated and untreated fruits.
Fig. 8: Fruit firmness (---) and T.S.D. (....) changes of bananas treated with 10 ppm ethylene (○), 1000 ppm acetylene (●) and 200 ppm ethrel (□) compared to untreated fruits (■) at 20 °C and 90 - 95% R.H. Vertical bars (I) show the L.S.D. (1%) in each day.
Fig. 9: Total sugar content changes during ripening of bananas treated with 10 ppm ethylene (○), 1000 ppm acetylene (●) and 200 ppm ethrel (▲) compared to untreated fruits (△) at 20°C and 90–95% R.H. Vertical bar shows the L.S.D. (1%).
Fig. 10: Total phenolic content changes during ripening of bananas treated with 10 ppm ethylene (-----), 1000 ppm acetylene (-----) and 200 ppm ethephon (-----) compared to untreated fruits (▲) at 20°C and 90 - 95% R.H. Vertical bars (†) show the L.S.D. (1%).
Fig. II.

Graph showing the change in pH over days after treatment.
4.2.3. Fruit Acceptability of Bananas Ripened by Different Ripening Reagents.

For sweetness (Fig. 12.a) panelists gave mean scores of 4.1, 4.05, and 4.1 for peeled and 4.35, 4.35 and 4.25 for unpeeled bananas treated with ethylene, acetylene and ethrel, respectively. Mean scores of 3.25 and 4.0 were given for aroma of bananas treated with the three reagents when peeled and unpeeled, respectively (Fig. 12.b).

Softness scores (Fig. 12.c) showed mean scores of 5.15, 5.1 and 5.1 for peeled and 5.0, 3.05 and 3.0 for unpeeled bananas treated with ethylene, acetylene, and ethrel, respectively.

For general eating quality (Fig. 12.d), consumers gave a mean score of 7.5 for peeled and 8.1 for unpeeled bananas treated with the three reagents used. No significant differences were found between the three reagents applied, but unpeeled fruits got significantly higher scores than peeled ones in sweetness and aroma.
Fig. 12: Mean scores given by 20 panelists for (a) sweetness, (b) aroma, (c) softness and (d) general eating quality of peeled (□) and unpeeled (■) bananas treated with 10 ppm ethylene (A), 1000 ppm acetylene (B) and 300 ppm ethyl (C) and ripened at 20°C and 90–95% R.H. Vertical bars show the L.S.D. (1%).

Firmness was 2.2, 1.55 and 1.05 kg/cm² in the charcoal, air-conditioned and mechanically refrigerated ripening rooms, respectively. Firmness of 2.0 and
Table 1: Ripening conditions of temperature and 2.6. - color score, pulp firmness, total soluble solids, and weight loss of bananas ripened as bunches in the conventional charcoal, semi-improved air conditioned and mechanical refrigerated ripening rooms. All parameters determined after 4 and 7 days.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Temperature °C</th>
<th>R.H.%</th>
<th>Color change</th>
<th>Firmness kg/cm²</th>
<th>T.S.S.%</th>
<th>Wt. loss %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Days in Room</td>
<td>4</td>
<td>7</td>
<td>4</td>
<td>7</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>Charcoal room</td>
<td>19</td>
<td>60</td>
<td>3</td>
<td>2.13</td>
<td>16.66</td>
<td>11.76</td>
</tr>
<tr>
<td>Air conditioned room</td>
<td>30</td>
<td>72</td>
<td>3</td>
<td>2.05</td>
<td>15.85</td>
<td>9.5</td>
</tr>
<tr>
<td>Leach, refriger. room</td>
<td>20</td>
<td>90</td>
<td>5</td>
<td>1.6</td>
<td>10.5</td>
<td>21.2</td>
</tr>
<tr>
<td>L.S.D.</td>
<td>0.27</td>
<td>0.253</td>
<td>2.1</td>
<td>1.06</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
1.6 kg/cm² were recorded after 4 days for fruits ripened in the air-conditioned and mechanically refrigerated rooms, respectively.

Total soluble solids were 16.66, 19.0 and 21.2% for fruits ripened in the charcoal, air-conditioned and mechanically refrigerated rooms, respectively. Total weight loss was found to be 11.76% in the charcoal room, 15% in the air-conditioned room. Total soluble solids were recorded to be 14% and 18.5% and weight loss to be 4.8 and 3.3% after 4 days for fruits ripened in the air-conditioned and mechanically refrigerated rooms, respectively. Significant differences were found in pulp firmness, total soluble solids, and weight loss between fruits ripened under the conditions of three ripening rooms.

When tomatoes were ripened as hands, the ripening period was 7 days in the mechanically refrigerated and air-conditioned rooms while it was 4 days in the charcoal room (Table 2). At the end of the ripening period, fruits ripened in the
<table>
<thead>
<tr>
<th>Rooms</th>
<th>Ripening period</th>
<th>Color score</th>
<th>4 days</th>
<th>7 days</th>
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<tbody>
<tr>
<td>Charcoal room</td>
<td>4</td>
<td>3</td>
<td>6.89</td>
<td>-</td>
</tr>
<tr>
<td>Air-conditioned room</td>
<td>7</td>
<td>5</td>
<td>4.63</td>
<td>9.73</td>
</tr>
<tr>
<td>Mech. refriger. room</td>
<td>7</td>
<td>7</td>
<td>3.27</td>
<td>6.63</td>
</tr>
</tbody>
</table>
mechanically refrigerated room were at color score No. 7. Those ripened in the air-conditioned room were at color score No. 5, while those ripened in the charcoal room were at color score No. 3 (table 2).

Weight loss after 4 days was 3.27, 4.93, and 6.89% for fruits ripened in the mechanically refrigerated, air-conditioned, and charcoal rooms, respectively. After 7 days, losses were 6.43 and 9.73% for fruits ripened in the mechanically refrigerated and air-conditioned rooms, respectively (table 2).

The pulp firmness declined progressively from 9.2 kg/cm² to 1.6, 1.44, and 1.52 kg/cm² at the end of the duration in the mechanically refrigerated, air-conditioned, and charcoal ripening rooms, respectively. The differences were significant (fig. 13).

Total soluble solids progressively increased from 4.0% to 21.5, 19.6, and 18.2% in the mechanically refrigerated, air-conditioned, and charcoal ripening rooms, respectively. These figures were significantly different (fig. 13).
Fig. 13: Pulp firmness (---) and total soluble solids (----) changes during ripening of bananas (Handu) in mechanically refrigerated room (●), semi-improved room (○) and conventional charcoal room (Δ). Vertical bars (I) show the L.S.D. (α).
4.3.2. Effect of Ripening Conditions on Fruit Quality.

Total soluble solids were 16, 13.7 and 10.5%; total sugars were 1.9, 1.19, and 0.32 mg/%, pulp and total phenolics were 0.75, 0.5, and 50.5 mg/%, pulp in bananas ripened in the mechanically refrigerated, air conditioned, and charcoal ripening rooms, respectively. Differences in the three parameters (total sugars, total sugars and total phenolics) between fruits ripened under the three different conditions were highly significant (Table 3). Also there was no difference in ascorbic acid and pH.

4.3.3. Effect of Ripening Conditions on Fruit Acceptability.

For acceptability (Table 5), panelists gave mean scores of 3.25, 3.1 and 3.1 for peeled and 4.25, 4.0 and 2.86 for unpeeled fruits ripened in the mechanically refrigerated, air conditioned and charcoal rooms, respectively. Differences between fruits from the first two rooms was not significant, but both were significantly different from the charcoal room.
Table 2: Total soluble solids, total sugars, total phenolics, pH and organic acid content of bananas at 1.63 kg/cm² pulp firmness ripened in charcoal room, air-conditioned room, and mechanically refrigerated room.

<table>
<thead>
<tr>
<th>Regime</th>
<th>T.S.S. %</th>
<th>Total sugars m/g pulp</th>
<th>Total phenolics mg/l pulp</th>
<th>pH</th>
<th>Acidic solids m/g pulp</th>
</tr>
</thead>
<tbody>
<tr>
<td>Charcoal room</td>
<td>10.3</td>
<td>103.7</td>
<td>58.5</td>
<td>4.3</td>
<td>10.3</td>
</tr>
<tr>
<td>Air-</td>
<td>13.7</td>
<td>119</td>
<td>85.9</td>
<td>4.8</td>
<td>10.5</td>
</tr>
<tr>
<td>conditioned</td>
<td>room</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reich.</td>
<td>16</td>
<td>137</td>
<td>99.7%</td>
<td>4.6</td>
<td>10.9</td>
</tr>
<tr>
<td>Refrigeration</td>
<td>room</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L.S.D</td>
<td>9%</td>
<td>1.03</td>
<td>11.9</td>
<td>3.0%</td>
<td>3.5</td>
</tr>
<tr>
<td></td>
<td>1%</td>
<td>1.48</td>
<td>17.44</td>
<td>14.33</td>
<td></td>
</tr>
</tbody>
</table>
Bananas ripened in the mechanically refrigerated room were given a mean score of 3.4 when peeled and 3.5 when unpeeled for aroma. Those ripened in the air-conditioned room scored 3.0 when peeled or unpeeled. Bananas ripened by the traditional charcoal method were given a mean score of 2.4 when peeled and 2.5 when unpeeled (Fig. 14.4).

Softness showed a mean score of 3.0 for peeled or unpeeled fruits ripened in the three ripening rooms (Fig. 14.5).

Mean scores of 7.46 and 6.86 were given for general eating quality of peeled and unpeeled fruits ripened in the mechanically refrigerated and air-conditioned ripening rooms, respectively. Panelists gave a mean score of 4.8 for peeled and 5.4 for unpeeled fruits ripened in the traditional charcoal. No difference was found between fruits from the first two rooms in softness, aroma and eating quality, but they were significantly different from those ripened by the traditional charcoal method.
Fig. 14: Mean scores given by 20 panelists for (a) sweetness, (b) aroma, (c) softness and (d) general eating quality of peeled (□) and unpeeled (■) fruits at 1.63 kg/cm² pulp firmness ripened in mechanically refrigerated room (R₁), semi-improved air-conditioned room (R₂) and conventional charcoal room (R₃). Vertical bars show the L.S.D. (1%).
Traditions play a major role in determining food quality. Generally, Eastern people prefer sweets more than Western people. This study showed that Sudanese consumers preferred the full ripe bananas (Stage 6, 7, and 8). These stages are the sweetest stages of ripeness. American consumers preferred the half ripe banana to the green and full ripe ones (50). Eighty-nine percent of the American consumer preferred bananas at stage 6, 5, and 6 while only 22 preferred stage 7 and 4% preferred stage 2 and 3 (19).

This study showed that consumers could easily detect the differences in sweetness and softness. It was noted that they detected, with some difficulty, the differences in aroma between the six stages. This was probably due to presence of large number of fruit samples in front of them giving off banana flavor. However, aroma results were similar to those of sweetness and softness. For general eating quality, the highest score was given to stage 8 followed by stage 7.
when unpeeled. These stages have yellow peel color with brown flecks. Japanese consumers called bananas with such peel "Abu-Nagthah". Most of them considered Abu-Nagthah to be the best variety, while it is actually a stage of ripeness.

Ripening temperature greatly affect fruit quality and fruit acceptability (34, 58, 61). This study showed that high temperatures affected sweetness of fruit as well as aroma and softness. This confirmed the results obtained by Lixana (53, 54) who reported that sucrose and volatiles of banana fruit were greatly suppressed during ripening at high temperature and those obtained by Yoshioka et al. (105) who reported an inhibition of chlorophyll degradation in bananas ripened at elevated temperatures. This study indicated that consumers preferred bananas ripened at 20°C and 50 - 95% R.H. with golden yellow peel and higher scores of sweetness, aroma, softness and general eating quality compared to those ripened at high temperatures (36 - 40°C) by charcoal method or at room temperature (25 - 29°C) which were ripe but green.
in color with lower scores for sweetness, aroma, softness and general eating quality. Consumers detected no differences between fruits ripened at 20°C and 90% - 95% R.H. either up to stage 7 or up to stage 4 and then transferred either to room temperature (26 - 29°C) or to 37°C.

Although there was no significant difference between peeled and unpeeled fruits in sweetness, aroma, softness, and general eating quality, color of peel had a permanent effect on consumer preference. In bananas ripened while green in color (those which ripened at high temperature by charcoal method) unpeeled fruits scored lower values compared to peeled ones. For instance, unpeeled bananas ripened by the charcoal method scored 22, 12.5, 14 and 20.25 lower values than did peeled fruits for sweetness, aroma, softness and general eating quality, respectively. On the other hand, in yellow bananas ripened at 20°C and 90% - 95% R.H., unpeeled fruits scored higher values for sweetness, aroma, softness and general eating quality than peeled fruits. For instance, unpeeled bananas ripened continuously
at 20°C scored 6.3, 15.8 and 5.7% higher values than peeled fruits for sweetness, aroma, and general eating quality, respectively. This showed the effect of skin color on consumer preference. Consumer preference to yellow fruit and resistance to green one in a matter of common knowledge. (54)

Sudanese consumers prefer sweet, soft, yellow fruits with brown shells. The findings of these experiments revealed that the best stage to remove fruits from the controlled conditions to the market was stage 4. Usually, fruits after removing from the ripening room are exposed to higher temperatures in the market. This has been noticed to increase the ripening rate and shorten the shelf life. Thus, if fruits are removed at stage 6, 7 or 8 (the stages preferred by the Sudanese consumers), they will become over ripe with weakness in each and peel and poor color in few hours due to high temperature and low R.H. (39). The term "cooked" is usually used to describe this type of injury in its extreme stage. In addition, keeping fruits till reaching full ripe stage will cost more. On the other hand, fruits at
color stage 4 are not yet ripe, and moderately firm for distribution and handling, and with a shelf life of 2 – 5 days prior to developing senescent spotting (stage 7)\(^{(58)}\). Stage 4 is also recommended in the U.S.A. for removal of bananas from ripening room to retailers\(^{(54, 46, 58)}\).

Dwarf cavendish bananas are widely grown in Sudan. Giant cavendish was recently introduced and grown in few private orchards. This study revealed that consumers couldn’t detect the differences in sweetness, aroma, softness, and general eating quality when similar-sized fruits of both types were presented to them. When fruits of each type were at full size, consumers preferred Giant to Dwarf. That showed the effect of fruit size on consumer preference, since Giant fruits are naturally larger in size than Dwarf when both are at the same maturity.

From the results obtained from the previous experiments, 20°C is the best ripening temperature for bananas. Ripening reagents are needed to trigger ripening and to shorten the ripening period. Ethylene,
acetylene and ethylene triggered ripening at all concentrations used. The higher the concentration the higher the ripening rate to the higher concentrations used. Ethylene gas at 1000 ppm was the best treatment and fruits treated at this concentration reached color index no. 4 after 2.75 days while untreated fruits reached that stage in 13.75 days. Liu (92) reported that effect of ethylene was dependent on maturity grade and temperature. He found that at constant temperature (21°C), 0.5 ppm took only one day to go through ripening with fully mature bananas, while with light fully three-quarter mature fruits it took 2.5 days. He also found that ethylene concentration of 0.015 - 0.05 ppm (which is less than the internal concentration 0.05 - 0.2 ppm) could trigger ripening when bananas were held at 40°C. Ripening rate was slower with acetylene gas. In this study, ethylene was found to be 100 times more effective than acetylene. This is in agreement with the findings of Fantastico and Mendosa (97) and Tsai and Chiang (92). The best concentration of acetylene was 1000 ppm. Higher concentrations gave the same ripening
rate obtained by 1000 ppm and caused fruit peel to split and break when peeled. Finger drop and peel split were found to be related to ripening conditions, especially temperature, but no investigations on the effect of ripening reagents were carried out.

Acetylene is explosive at 25000 ppm (91). It reacts with copper and produces a highly explosive product (91). For these reasons acetylene is not recommended where ethylene is available. However, acetylene is a conventional ripening reagent in some countries (78). The effective concentration of acetylene for banana ripening (1000 ppm) is well below the explosive concentration (25,000 ppm). If it is possible to avoid using copper in ripening rooms, acetylene will be the most suitable reagent for banana ripening in Swan for its availability and low price.

Ethanol triggered ripening at all concentrations used. The higher the concentration, the higher the ripening rate up to 200 ppm. At 200 ppm and above, bananas reached color index No. 4 similarly in 3 days.
In this study etheルl was found to be 20 times less effective than ethylene. Russo et al[77] reported that ethylene is 10 times more effective than etheルl.

The best method for etheルl application was found to be by dipping fruits in etheルl aqueous solution for 5 min. Spraying fruits with etheルl solution gave the same ripening rate that obtained by dipping fruits for 1 min. Dipping insures complete coverage of fruits with etheルl and thus efficient penetration through the pedicle scar which was reported to result in faster ripening rate compared to penetration through equatorial portions[68]. However, spraying is practically easier to apply and suitable for large scales.

Etheルl has the disadvantage that it has to be applied to fruits in an aqueous solution, an extra step in handling, that increases the cost. On the other hand, no especial arrangements like gas confinement needed with ethylene gas are required with etheルl provided ambient temperatures within the range required to ripen the commodity[90]. Etheルl has good effects
on initiation of banana ripening (27, 68, 70, 77), but it has not released yet for commercial fruit ripening because of the residues (chloride and phosphate) (99) resulting from release of ethylene from ethrel solution.

Bananas treated with ethylene at 10 ppm, acetylene at 1000 ppm and ethrel at 200 ppm had the same ripening rate. They also had similar total soluble solids, total sugars, total phenolics, pH and pulp firmness. This may be because ripening reagents do not contribute to fruit composition, but trigger ripening and shorten the ripening period. Also it was reported that the effect of ethylene on ripening rate and fruit quality was duplicated by acetylene (10, 55) and ethrel (70). The initial total soluble solids and total sugars content of the treated fruits increased about 5.6-fold and 20-fold, respectively, while the pH, total phenolics and fruit firmness decreased by 20, 60 and 75%, respectively. These changes were found to occur during banana fruit ripening (56). They were reported to commence with the commencement of the climacteric (61). Untreated fruits
remained at the initial fruit firmness, total soluble solids and total sugars. Total phenolics decreased in a lower rate in untreated fruits and so did pH. Consumers did not find any differences between the fruits treated with the three reagents. They considered them of the same eating quality. This confirmed the results obtained by Thompson and Seymour (91).

Fruit color had a great effect on consumer preference in all parameters tested. Unpeeled fruits scored higher values for sweetness, aroma and general eating quality than the peeled ones. This is because fruits were at stage 6 (all yellow) when the test was held.

Three different methods of banana ripening are being used in ripening rooms in Khartoum. These are the conventional banana ripening method, burning charcoal to trigger ripening; the semi-improved air conditioned room and improved mechanically refrigerated ripening room. This study revealed the highest weight loss in the charcoal room. Weight loss of 11.26% was recorded in this room within 4 days.
In the semi-improved air conditioned room, 5.7 and 15% weight loss were recorded within 4 and 7 days, respectively. Only 5.6% weight loss were recorded in the mechanically refrigerated room within 4 days, while 6.2% were recorded within 7 days. This might be attributed to the differences in temperature and relative humidity utilized in these different types of ripening rooms. The highest relative humidity was recorded in the mechanically refrigerated room (90 - 95%) followed by the air conditioned room (72 - 77%) then the charcoal room (60 - 62%). At the same time the highest temperature was recorded for the charcoal room (36 - 44°C) followed by the air conditioned room (22 - 34°C) then the mechanically refrigerated room (20°C). Similar results were obtained by many investigators using different crops (4, 20, 72, 75, 85, 100). These investigators reported that high temperatures and low relative humidity increased the weight loss via enhancement of respiration and water loss. Also the study showed that the higher the relative humidity and the lower the temperature in the ripening room the
higher the total soluble solids and the lower the fruit firmness. Weight loss was higher in fruits ripened as bunches rather than in hands, especially in the traditional and the air conditioned rooms. This might be due to the stacking pattern used in these rooms which caused great mechanical damage to fruits resulting in high weight loss. Weight loss of 18 - 20% during ripening period in Sudan was recorded by Salih (86). Results revealed that fruits in the refrigerated room ripened in the shortest period with the lowest weight loss. Conditions in this room (20°C and 90 - 95% relative humidity) are the recommended conditions for commercial bunches ripening (95). When studying the effect of the ripening room conditions on fruit quality at the same stage of pulp firmness (1.69 kg/cm²), it was found that ascorbic acid and pulp pH were not affected by these conditions. There is some evidence that storage temperatures in excess of 27°C for months can cause a loss of ascorbic acid (96). In this study, the period of exposure was probably not enough to cause losses in fruits ripened at high
temperatures. Total soluble solids and total sugars were greatly affected by the ripening room conditions. Low sugars and total soluble solids content were detected in fruits ripened in the conventional charcoal room (36 - 44°C and 60 - 67% relative humidity). This is in agreement with the results obtained by Liana (53) who reported that no sweetness was detected in fruits ripened at 40°C in ethylene free air but some sweetness developed when fruits continuously gassed with 30 ppm ethylene. Total sugars decreased at temperatures above 40°C due to decrease in sucrose. Liana (54) found that noticeable suppression of sucrose concentration occurred in bananas ripened at 40°C, but fructose and glucose remained unaltered. The highest total soluble solids and total sugars were recorded for the mechanically refrigerated room followed by the air conditioned room and then the conventional charcoal room. Total phenolics decreased in all fruits. The highest rate was recorded for the charcoal room followed by the semi-improved air-conditioned room. This is probably due to thermal inactivation of phenoloxidase enzymes.
Confirming the above results consumers preferred fruits ripened in the mechanically refrigerated room followed by those ripened in the air-conditioned room and then those ripened in the charcoal room.
Good quality bananas are produced for local market in Sudan. However, ripe fruits displayed in the market are of poor quality. This piece of work was conducted to improve banana ripening conditions and methods applied in Sudan. Banana variety and ripening stage preference of Sudanese consumers are other purposes of this study.

This study revealed that Sudanese consumers preferred full ripe bananas (stages 6, 7 and 8). For general eating quality, the highest score was given to stage 6 followed by stage 7 when unpeeled. These stages have yellow peel color with brown flecks. Sudanese consumers called bananas with such peel "Abu-Nugrah".

Ripening temperature greatly affects fruit quality and acceptability. This study indicated that consumers preferred bananas ripened at 28°C and 90-92% relative humidity with golden yellow peel and golden scores for sweetness, aroma, softness and general eating quality compared to those ripened at higher
temperatures (30 - 45°C) by charcoal method or at room temperature (24 - 29°C) which were ripe but green in color had lower scores of sweetness, aroma, softness and general eating quality.

Consumers considered Dwarf and Giant condemning banana of the same size to be of similar quality. While when both types were tested at the same maturity, the Giant, which is larger in size, was preferred to the Dwarf.

Feel color affected the consumer preference although differences were not significant. Unpeeled banana ripened while green in color scored lower values of sweetness, aroma, softness, and general eating quality compared to peeled ones, while unpeeled yellow banana scored higher values than peeled ones.

Ripening temperature of 25°C is the best temperature for banana ripening. Ripeing reagents are needed to trigger ripening and shorten the ripening period. Untreated fruits remained firm and green for 12 days and reached color index No. 4 after 13.75 days. Ethylene, acetylene and ethyl alcohol triggered ripening at all
concentrations used. The higher the concentration the quicker the ripening rate of the bananas. Ethylene at 1000 ppm was the best treatment and fruit reached color index No. 4 in 8.75 days. Ethylene was 100 times more effective than acetylene and 50 times more effective than ethylene. Ethylene at 10 ppm, acetylene at 1000 ppm and ethene at 200 ppm gave the same ripening rate and the same effects on fruit quality and acceptability.

Ripening conditions in different ripening rooms in Xharimun area were studied. Fruits ripened in the mechanically refrigerated room attained the best quality and acceptability compared to fruits ripened in the conventional room using charcoal and the semi-separated air conditioned ripening room.
هناك كميات كبيرة ذات جودة عالية من المواد الأملاحية للنوى الجلالي في الصودا، الأمر الذي يشير إلى أن السوق ذات جودة عالية. هذا النوع من المواد الأملاحية يتغير ظروف الاستخدام والظروف المستمرة في الصودا، حيث أن التغييرات في الصناعة والتصنيع المتحاليف لاستخدام الصودا، بدأ في أواخر هذه الدراسة.

هذه الدراسة أظهرت أن المستهلكين الصودانيين يفضلون الزيت الزيت النقي (مرحله 1 و 2) بالإضافة إلى المواد الخامه في أطعمة الأقم. أظهرت هذه المرحلة 3، عندما تكون فاصل عودة غير مضطرب، أن هذه المرحلة من القدرة لها تسعة مواد متماثلة ببطء نقي. الفاصل يرتبط الصودانيون ببعض المعه بهذه الدراسة (التي أظهرت).

درجة حرارة الزيت تؤثر بعدة جوهرات على حرارة ودرجة
نحو الزيت، هذه الدراسة تلت على أن المستهلكين الصودانيين يفضلون الزيت الذي يتم انصهاره على درجة حرارة 200 م، ودرجة حرارة 100 م، والذي يكون له تغيرات أقل. ولاحقاً، يمكنه أن يكون من درجة حرارة عالية (220-235 م) باستخدام درجة حرارة القليلة (215-220 م) الذي تكون في ارتفاع في درجة حرارة، والكابينة والطبيعة والزوجة العامة.
المستقبل السوادي على مر النافذة (Giant) وصة (Giant) في درجة واحدة من الميزة وصفة (Breed) ميزة (Maturity)

لكن القشرة لا تأتي فقط من تغليف المستقبل السوادي للحوم رغم أن الأعراض لم تكن مبسطة. شارب النمر مثيرة ونقي، لولا أن كانت بذلك شارب شام، ستجد في درجة الميزة والتكاثر والليونة والجميل النمام أقل من نسمات قشرة النمر الذي كان أظهرًا. هذه القشرة التي تشد بشكل مثيرة، سجلت تقدم أكبر من نسمات قشرة النمر.

درجة حرارة النخاع 280ум هي أقصى درجة لإنزاح النخاع. الميزة المتساوية في النخاع تصل نسبة الألف (Giant) وصة (Giant) في درجة واحدة من الميزة وصفة (Breed) ميزة (Maturity)

لكن القشرة لا تأتي فقط من تغليف المستقبل السوادي للحوم رغم أن الأعراض لم تكن مبسطة. شارب النمر مثيرة ونقي، لولا أن كانت بذلك شارب شام، ستجد في درجة الميزة والتكاثر والليونة والجميل النمام أقل من نسمات قشرة النمر الذي كان أظهرًا. هذه القشرة التي تشد بشكل مثيرة، سجلت تقدم أكبر من نسمات قشرة النمر.

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النحو والابتكار يركز على جزءًا في النحوين الحروف، لبناء النواة الإضافية والتأثيرات على حركة الحروف ودرجة تقبلها.

أبودت الإضاف في غرض الإضاف في مشاركة الحروف، نشأت دراستها. الأبار التي أنتجت في الحروف المبتدئة سكّانها وحلكت لأعلى حركة ودرجة تقبل لدى المستفيضين، مادة مقاسة التي أصبحت في القوس التلقائي باستخدام النوى، والتي أضحت في القوس التي تستخدم كمات النوى.
CONCLUSIONS

The experiments were conducted to explore the ripening conditions of bananas in Sudan; temperature, relative humidity, and ripening initiators and the effect of those factors on banana quality.

It can be concluded, in a point system, that:

1- The method of stacking of bananas in ripening room should be in hand or clusters on shelves as opposed to the bunch stacking on floor of room as is being traditionally practiced. Stacking of hands or clusters on shelves resulted in less water loss possibly because of the improper air circulation and thereby inefficient cooling down of stacks. Stacking on bunches is not suitable for ripening by ethylene to stage 4 as this caused crushing of fingers.

2- The optimum ripening conditions for bananas are 20°C and 90 - 95% relative humidity with application of a ripening reagent, compared to the traditional and the semi-improved conditions commercially used.
Panel tests showed that the most suitable stage to remove bananas from the ripening room was stage 4 (more yellow than green). At this stage the quality is not good enough for eating, but when exposing fruits to ambient condition in the market this will increase the respiration and hence enhance the ripening.

Of the ripening initiators tested (ethylene, acetylene, ethrel), ethylene proved to be the most efficient. Acetylene, which is available in the local market, has the disadvantage of causing corrosion of copperic materials if they are used in cooling unit pipes. Ethrel, which is money to use, is not yet released for use in banana ripening. More investigations are needed to study the hazardous effect of the residues resulted from breakdown of ethrel inside fruit tissues.
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APPENDICES
Please taste the samples in front of you and record the number which best describe what you feel when tasting each sample according to the following scales:

**I - Sweetness**

<table>
<thead>
<tr>
<th>Score</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>very starchy (inedible)</td>
</tr>
<tr>
<td>2</td>
<td>starchy (but edible)</td>
</tr>
<tr>
<td>3</td>
<td>intermediate</td>
</tr>
<tr>
<td>4</td>
<td>sweet</td>
</tr>
<tr>
<td>5</td>
<td>very sweet</td>
</tr>
</tbody>
</table>

**II - Aroma**

<table>
<thead>
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<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>none</td>
</tr>
<tr>
<td>2</td>
<td>poor</td>
</tr>
<tr>
<td>3</td>
<td>intermediate</td>
</tr>
<tr>
<td>4</td>
<td>strong</td>
</tr>
<tr>
<td>5</td>
<td>Very strong</td>
</tr>
</tbody>
</table>

**III - Softness**

<table>
<thead>
<tr>
<th>Score</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>too firm (inedible)</td>
</tr>
<tr>
<td>2</td>
<td>firm (but edible)</td>
</tr>
<tr>
<td>3</td>
<td>soft</td>
</tr>
<tr>
<td>4</td>
<td>very soft (but edible)</td>
</tr>
<tr>
<td>5</td>
<td>juicy (inedible)</td>
</tr>
</tbody>
</table>

**IV - General Rating Quality**

<table>
<thead>
<tr>
<th>Score</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Inedible</td>
</tr>
<tr>
<td>2</td>
<td>Very poor</td>
</tr>
<tr>
<td>3</td>
<td>Definitely poor</td>
</tr>
<tr>
<td>4</td>
<td>Slightly poor</td>
</tr>
<tr>
<td>5</td>
<td>Intermediate</td>
</tr>
<tr>
<td>6</td>
<td>Fairly good</td>
</tr>
<tr>
<td>7</td>
<td>Good</td>
</tr>
<tr>
<td>8</td>
<td>Very Good</td>
</tr>
<tr>
<td>9</td>
<td>Excellent</td>
</tr>
</tbody>
</table>
### Appendix 1 contd.

<table>
<thead>
<tr>
<th>Panelist number</th>
<th>Sample number</th>
<th>Sweetness score</th>
<th>Aroma score</th>
<th>Softness score</th>
<th>Rating Quality score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Fossil Unsealed</td>
<td>Fossil Unsealed</td>
<td>Fossil Unsealed</td>
<td>Fossil Unsealed</td>
</tr>
</tbody>
</table>
Appendix 3
Total Sugars Assay
Anthrone Method

Preparation of Standard Curve:

1- Dissolve 20 mg of glucose in 200 ml distilled water to get a solution of a concentration of 100 mg/ml.

2- Take 1 ml from this solution and make up to 10 ml with distilled water to get a 10 mg/ml solution.

3- From the latter solution (10 mg/ml) prepare 6 concentrations for standard curve as follows:

- 0.0 ml from (10 mg/ml) + 1.0 ml H₂O → 0.0 mg sugars (blank)
- 0.2 ml from (10 mg/ml) + 0.8 " " → 2.0 mg "
- 0.4 " " " + 0.6 " " → 4.0 mg "
- 0.6 " " " + 0.4 " " → 6.0 mg "
- 0.8 " " " + 0.2 " " → 8.0 mg "
- 1.0 " " " + 0.0 " " → 10 mg "

Anthrone Solution: 200 mg anthrone/100 ml conc. H₂SO₄

Procedure:

1- Place 1 ml of the tested solution in test tube (containing 10-100 gamma sugars).

2- Add 2 ml of anthrone solution.

3- Mix well on tube mixture.

4- Heat for 8 minutes in boiling water (particularly necessary for small samples)

5- Read at 620 mµ.
Appendix 4

Determination of Total Phenolics
Using Folin-Ciocalteu Reagent

Preparation of Standard Curve:

1. Dissolve 1 g of tannic acid in 200 ml distilled water to get a 5 mg/ml solution.

2. Take 4 ml from this solution and make up to 100 ml with distilled water to get a 0.2 mg/ml solution.

3. Take 1 ml from the latter solution (0.2 mg/ml) and make up to 10 ml with distilled water to get a 0.02 mg/ml solution (solution a).

4. Prepare 5 different concentrations from solution a as follows:

<table>
<thead>
<tr>
<th>Take</th>
<th>Solution</th>
<th>Concentration (µg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5 ml</td>
<td>A + 1 ml H₂O</td>
<td>0.4 µg tannic (Blank)</td>
</tr>
<tr>
<td>0.4 ml</td>
<td>&quot; + 1.6 &quot;</td>
<td>4.0 µg &quot;</td>
</tr>
<tr>
<td>0.8 ml</td>
<td>&quot; + 1.2 &quot;</td>
<td>8.0 µg &quot;</td>
</tr>
<tr>
<td>1.2 ml</td>
<td>&quot; + 0.8 &quot;</td>
<td>12.0 µg &quot;</td>
</tr>
<tr>
<td>1.6 ml</td>
<td>&quot; + 0.4 &quot;</td>
<td>16.0 µg &quot;</td>
</tr>
</tbody>
</table>
Appendix IV contd.

Procedure:

1. Pipette 1 ml of the fruit tissue extract to a 50 ml Erlenmeyer flask and then add 9 ml of distilled water. Mix thoroughly.

2. Pipette 2 ml of diluted sample in a test tube.

3. Add 10 ml of diluted (1:9 distilled water) Folin - Ciocalteu reagent and mix well.

4. Between 30 seconds after addition of Folin - Ciocalteu reagent but before 8 minutes have elapsed, add 8 ml of sodium carbonate solution (0.075 g of Na₂CO₃ per ml). Mix well again.

5. Place your test tubes for one hour at 30°C (86°F) and then transfer them to 0°C (32°F) for approximately another hour (usually 30 minutes is sufficient).

6. Read absorbance at 750 nm.
Appendix 5
Determination of Ascorbic Acid

Procedure
1- Take 30 gm of fruit and blend with reasonable amount of 0.4% oxalic acid.
2- Filter by filter paper No. 1.
3- Make up to 250 ml with 0.4% oxalic acid.
4- Pipette 20 ml of the solution into a beaker.
5- Titrate with dye (2,6 dichloroindophenol) to a faint pink color.

Calculations:

\[ \text{mg ascorbic acid/100 gm} = \frac{\text{ul(titration)} \times \text{dye strength} \times 100}{\text{factor}} \]

factor =

\[ \text{Sample wt (20 gm) \times sample volume for titration (20 ml) \times total volume of sample (250 ml)} \]
Appendix V cont'd.

Preparation of reagents:

- 0.4% oxalic acid: 4 gm oxalic acid / 1 litre distilled H₂O.

- 10% oxalic acid for measuring the dye strength:
  50 gm oxalic acid/500 ml distilled H₂O.

- Ascorbic acid for measuring dye strength:
  0.05 gm ascorbic acid/250 ml of 10% oxalic acid.

- Dye solution: 0.2 gm of 2,6-dichloroiodophenol/500 ml distilled H₂O.

Dye strength

1- Take 5 ml of 10% oxalic acid and add to it 5 ml ascorbic acid.

2- Titrate with dye to faint pink color.

$$\text{Dye strength} = \frac{1}{\text{titre}}$$