Sudan University of Science and Technology

Collage of Graduate Studies

Standard Specifications of Fruits of Grapefruit (*Citrus paradisi* Macf.) Foster and Duncan Cultivars in River Nile State- Sudan.

المواصفات القياسية لثمارصنفي القريب فروت فوستر و دنكان- ولاية نهر النيل - السودان

A thesis submitted in Partial fulfillments of the requirements for the Degree of Master of Science in Horticulture

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Dedication

This study associated with my thanks is

Dedicated to: the soul of my father

&Mother,

My brothers & Sister,

All my friends

And for every one reads this study

Acknowledgements

I would like to take this opportunity at first and foremost to thank God for giving me strength and guide to present this work in this form. I would like to express the deepest appreciation and great thanks to my supervisor Prof.Dr. Elsadig Hassan Elsadig Mohamed for his guidance, encouragement and suggestions. Special thanks are due to my family. I am grateful for all for their constant support and help

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Abstract

Grapefruit (*Citrus paradis*i Macf.) is an important crop in Sudan. The quality of grapefruit is affected by many factors which are suspected to cause the low yield and poor quality of fruits. These factors may include infection by pests and diseases, damage, soil problems and poor management practices. The present study aimed to identify the specifications of two grapefruit cultivars (Foster and Duncan).This was achieved through determining quality indices such as, number of segments, total soluble solid, pH, juice content, number of seeds, fruit diameter, fruit weight, fruit peel thickness, fruit firmness, and fruit length, The results showed that there were significant differences in some quality indices such as the higher quality of Foster fruit than the Duncan fruit, whereas Foster and Duncan have approximately the same standard specifications.

The study recommended developing activation and revision of laws that guarantee the quality of fruits and train producers to identify varieties and quality indicators and apply methods of modern transport and storage and cultivate new varieties of high economic value, open new markets outside Sudan and to promote grapefruit consumption, and use food processing and cosmetics. Continuation of research in the field of standards specification and modernization of markets are also recommended.

المستخلص

يعتبر القريب فروت محصول هام في السودان , تتأثر جودة القريب فروت بعدة عوامل تتسبب في انخفاض العائد و رداءة جودة الثمار . و تتضمن هذه العوامل الميكروبات، الاصابة بالتلف من الافات و الامراض، مشاكل التربة و ضعف العمليات الزراعية

تهدف هذه الدراسة الي التعرف علي المواصفات القياسية في القريب فروت لصنفي الفوستر والدنكان امكن تحقيق هذا من خلال تحديد مؤشرات الجودة مثل عدد الفصوص والمواد الصلبة الذائبة الكلية (درجة الحلاوة) ورقم الاس الهيدروجيني و كمية العصير و عدد البذور وعرض الثمرة ووزن الثمرة و عرض قشرة الثمرة ودرجة صلابة الثمرة و طول الثمرة .

اظهرت النتائج وجود فرق معنوي في بعض مؤشرات الجودة. كما اظهرت النتائج كذلك ان جودة ثمار صنف الفوستر اعلي من صنف الدنكان ,و رقم ذلك فان الصنفين لديهم تقريباً نفس المواصفات القياسية العالمية.

اوصت الدراسة بتطويرو تفعيل ومراجعة القوانين التي تضمن سلامة الثمار , و تدريب المنتجين لمعرفة الاصناف و مؤشرات الجودة و كيفية النقل و التخزين و زراعة اصناف جديدة ذات قيمة اقتصادية عالية وفتح اسواق جديدة خارج السودان و الترويج للقريب فروت و تشجيع استهلاكه و استخدامه في الصناعات الغذائية و مستحضرات التجميل. كما اوصت الدراسة بمواصلة البحوث في مجال المواصفات و تحديث الاسواق.

Chapter One

Introduction and Literature review

1.1 Introduction

Grapefruit (*Citrus paradis*i Macf.) was originally believed to be a spontaneous sport of the Pummelo, MacFayden,1837. separated grapefruit from the Pummelo, giving it the botanical name, *Citrus paradisi* Macf (Morton, 1987).

Citrus is an important cash crop and an essential source of human diet, especially, vitamin C (Economos and Clay, 1999). Total area of citrus in Sudan is estimated as 42,000 hectare, 103784 ac (SNHA, 2001). Therefore, the national strategy for expansion of citrus production was directed towards the large national schemes such as Gezira, Rahad, Suki and the Blue Nile schemes in the Central Clay Plain (Sidahmed and Geneif, 1984a). Soils of this area are characterized by high clay contents, high pH, low organic matter, hence, low nitrogen level (Ali *et al*, 2003).The world production of grapefruits and pummelo is 4 million tons and is grown in 74 countries on about 264,000 ha (Gmitter *et al*, 2009), and the annual production of grapefruits in Sudan in 2005 was 67 000 tons (FAO 2005).

Judging by palatability and external appearance, the quality of grapefruit grown in Sudan has been commended as superior to fruits grown in other leading citrus-producing areas (Robbie and Fisher 1954).

To produce good quality, the grapefruit must meet standardized methods and good specifications. Many factors were suspected to cause the low yield and poor quality of fruits. These factors may include infection, damage, soil problems and poor management practices. Although the Sudan has a great potentially to produce and export high quality of grapefruit, yet application of

the standardized methods are not proper by followed and the specification is still not taken care of by many producers and distributors. This may affect indirectly production and directly affect market. In the present study we attempt to characterize the standard Sudanese specifications of grapefruit.

The present study aimed to identify the specification of grapefruit (Foster and Duncan cultivars) from River Nile State in Sudan. This can be achieved through determining, diameter, the number of seeds, number of lobes and the percentage of juice and total soluble solids. On the other hand the research can determine the pH, the peel thickness, firmness and weight of the two types of grapefruit toward the standarding characterization.

1.2 Literature review

1.2.1 Origin and characterizations of grapefruit

The Grapefruit (*Citrus paradis*i Macf.) was first described in 1750 by Griffith Hughes who called it the "forbidden fruit" of Barbados. In 1789, Patrick Browne reported it as growing in most parts of Jamaica and he referred to it as "forbidden fruit" or "smaller shaddock. At first, the tree was grown only as a novelty in Florida and the fruit was little utilized. Even in Jamaica, the trees were often cut down. By 1910, grapefruit had become an important commercial crop in the Rio Grande Valley and, to a lesser extent, in Arizona and desert valleys of California. (Morton, 1987).The grapefruit is grown only at small scale in the Orient where the Pummelo is cultivated. In recent years, the grapefruit has become established in India in hot regions where the Sweet Orange and the Mandarin are prone to sunburn (Morton, 1987).

The name grapefruit originated in Jamaica, and has been used since 1814(Sinclair, 1972a). Grapefruit is the third most important citrus in the world after Orange and Mandarins (FAO, 2004), and is one of the most important citrus fruits in Sudan. It can be successfully grown throughout the country where there are suitable soils and sufficient water to sustain the tree growth (Sidahmed and Geneif, 1984b).

1.2.2 Distribution

Citrus is one of the world's most important fruit crops due to its wide distribution (throughout the tropical and subtropical regions) and large-scale production (Gmitter *et al.* 2009).

Grapefruit is also grown commercially in Spain, Morocco, Israel, Jordan, South Africa, Brazil, Mexico, Jamaica, and Asia (Bhattacharya, *et al.* 2007). Further, varieties of grapefruit were developed mainly in Florida and Texas,

USA (Ortuno, *et al*. 2006). Today it is the second most important citrus worldwide and a key commercial crop in the U.S States of Texas, Arizona, California, and Florida. In Florida alone, more than 2.5 million tones of grapefruit are harvested annually. The U.S. now produces 60% of the world's grapefruit crop (Lucker, *et al*. 2002). *Citrus paradis*i is an important fruit in Pakistan and its production is increasing day by day due to its considerable medicinal importance (Khan, *et al*. 2010).Today citrus fruits are grown in all regions of the world where the climate is not severe during winter and suitable soil conditions exist. Also many desert regions have been opened for citrus culture by the development of irrigation facilities. Frost and cold protection techniques extend the growing regions further north, where previously citrus could not be grown profitably (Ting and Attaway, 1971).

Sudan ranked second, after South Africa, in production of grapefruit in Africa, with a total production of 65000 tons compared to 212181 tons in South Africa (FAO, 1999).

Production of grapefruit in Sudan during the years of (2006-2011) was 199000, 156000, 165000, 174000, 183000, and 184325 (tons) respectively (FAOSTAT, 2013). Sudan is among the leading Arab countries for grapefruit production (Table1).

Table 1: Production of grapefruit from 2006-2011 (in 1000 MT) in the Arab countries.

Country	years					
	2006	2007	2008	2009	2010	2011
Sudan	199000	156000	165000	174000	183000	184325
Lebanon	16200	15200	11700	17000	7500	7000
Jordan	4756	7789	9835	8107	8439	7566
Egypt	3810	2350	2215	2192	2237	2338
Algeria	2530	1010	1044	1139	1656	2040
Morocco	1000	1010	1000	1100	1000	1001

Source: FAOSTAT, (2013)

1.2.3 Cultivars

Several grapefruit cultivars have been introduced into Sudan and were evaluated for their growth, yield, and fruit quality**,** (Dinar and Osman, 1984).

1.2.3.1 Duncan cultivar fruit (Plate .1)

The fruit is round or slightly obviate; large, 3½ to 5 in (9-12.5 cm) wide; peel is very light yellow (usually called "white"), with large oil glands, medium-thick, highly aromatic; pulp is buff, with 12-14 segments with medium-tender membranous walls, very juicy, of fine flavor; seeds medium-large, 30-50 (Morton, 1987).

1.2.3.2 Foster cultivar fruit (Plate .2)

Foster (Pink Flesh') Originated as a branch sport of a selection called 'Walters' in the Atwood Grove near Ellenton, Florida. It was discovered by M.B. Foster of Manatee in 1906, and propagated for sale by the Royal Palm Nurseries. Fruit is oblate to round; medium-large, averaging 3¾ in (9.5 cm) in width; peel light-yellow blushed with pink, smooth but with large, conspicuous oil glands; albedo pink; pulp light-buff, pinkish near the center; in 13 or 14 segments with pinkish walls, tender, juicy, of good quality despite seeds, up to 50 or even more, of medium size.The pulp being entirely pinkish in hue. Other Cultivars of grapefruit include Marsh, Oroblanco, Paradise Navel, Red Blush, Star Ruby Thompson, Triumph (Morton, 1987).

1.2.4 Description of the Tree

The grapefruit tree reaches 15 to 20 ft (4.5-6 m) height or even 45 ft (13.7 m) with age, it has a rounded top of spreading branches; the. The twigs normally bear short, supple thorns. The evergreen leaves are ovate, 3 to 6 in (7.5-15 cm) long, and 1 ¾ to 3 in (4.5-7.5 cm) wide; dark-green above, lighter

beneath, with minute, rounded teeth on the margins, and dotted with tiny oil glands; the petiole has broad, oblanceolate or obovate wings. The white, 4-petalled flowers, are 1 ¾to 2 in (4.5-5 cm) across and borne singly or in clusters in the leaf axils. The fruit is nearly round or oblate to slightly pear-shaped, 4 to 6 in (10-15 cm) wide with smooth, finely dotted peel, up to 3/8in (1 cm) thick, pale-lemon, sometimes blushed with pink, and aromatic outwardly; white, spongy and bitter inside. The center may be solid or semi-hollow. The pale-yellow, nearly whitish, or pink, or even deep-red pulp is in 11 to 14 segments with thin, membranous, somewhat bitter walls; very juicy, acid to sweet-acid in flavor when fully ripe. While some fruits are seedless or nearly so, there may be up to 90 white, elliptical, pointed seeds about 1/2 in (1.25 cm) in length. Unlike those of the pummelo, grapefruit seeds are usually polyembryonic. The number of fruits in a cluster varies greatly; a dozen is unusual but there have been as many as 20 (Morton, 1987).

1.2.5 Climate

The grapefruit prospers in a warm subtropical climate. Temperature differences affect the length of time from flowering to fruit maturity. Humidity contributes to thinness of peel, while in arid climates the peel is thicker and rougher and, as might be expected, the juice content is lower. Low winter temperatures also result in thicker peel the following year and even affect the fruit shape. Ideal rainfall for grapefruit is 36 to 44 in (91.4-111.7 cm) rather evenly distributed the year around (Morton, 1987).

1.2.6 Soil

The grapefruit is grown on a range of soil types. In the main growing area of Florida, the soil is mildly acid sand and applications of lime may be beneficial. On the east coast there are coquina shell deposits and, in the extreme southern part of the peninsula, there is little soil mixed with the

prevailing oolitic limestone. Where the grapefruit is grown in California, Arizona and Texas, the soils are largely alkaline and frequent irrigation causes undesirable alkaline salts to rise to the surface. In Surinam, grapefruit is grown on clay soils. Successful grapefruit culture depends mainly on the choice of rootstock best adapted to each type of soil. Salinity of the soil and in irrigation water retards water uptake by the root system and reduces yields (Morton, 1987).

1.2.7 Composition of the fruit

The composition of the fruit varies, not only with the degree of maturity, but also with climate, soil, variety, cultural practices, and other factors (Sinclair, 1972b).Elsadig and Suleiman (2013).Showed that the size of lime fruit increased at an increasing rate up to the seventh week of fruit development. The fresh weight of mature grapefruit consists of 35 to 50 % juice, with the remainder made up of peel, rag, and seeds. The fresh juice consists of 88 to 93% water, 8 to 13 % soluble solids, and small amounts of insoluble solids. Sugar (sucrose and reducing) and acids (chiefly citric) constitute 85 to 90% of the soluble solids; the other solids , soluble and insoluble, are mainly vitamins, mineral salts, amino acids, proteins , fats, pectin, and glycosides(Sinclair,1972b). Grapefruit and sour orange contain relatively less sugar and more citric acid between 1.5 and 3.0% (Samson, 1986) The fruit contains a bitter glycoside and naringin, which is found in large quantities in the peel (0.66 to 0.80% per 100g) of the fruit (Zoller,1918).

1.2.8 Harvesting

Harvesting of citrus for fresh market is done by hand in all countries. Normally, fruits are cut with hand clippers and collected in picking bags and then transferred to field containers and then transported to packing houses.

This system is carried out in some countries in the region especially for fruits intended for export (Tunisia, Egypt, Morocco, and Lebanon). However, for fruits to be consumed locally, and in other countries of the region (Libya, Sudan for example), fruits are collected by hand and placed in marketing boxes or bags with a capacity of about 5kg and transferred directly to the market. However, some sorting is usually done during picking to eliminate defected fruits. Care should be taken to handle the fruit carefully to reduce physical damage since losses during harvest of some fruits and vegetables in some countries of the region were estimated to be 4-12 percent (Kader, 1979).

Grapefruits were formerly harvested by climbing the trees or using picking hooks which frequently damaged the fruit. Today, the fruits on low branches are picked by hand from the ground; higher fruits are usually harvested by workers on ladders who snap the stems or clip the fruits as required. California began utilizing a modified olive limb-shaker for harvesting grapefruit in 1972, (Morton, 1987). The machines work in pairs to harvest opposite sides of each tree and the trees must be pruned to remove deadwood and to give access to 3-5 main limbs for shaking. Lower branches must be lopped off to leave a clear 2 1/2 ft (75 cm) space for the catching frame. Mechanical harvesting causes some superficial injury. A team of 3 workers with one machine can harvest 150 to 188 field boxes–50 lbs (22.7 kg) when filled–per hour, as compared with 45 boxes per hour for 3 manual pickers. Stems are removed from the fruits before packing to avoid stem-damage (Morton, 1987).

1.2.9 Keeping quality

The grapefruit keeps well at 65º F (18.33º C) or higher for a week or more and for 2 or 3 weeks in the fruit/vegetable compartment of the home refrigerator. The first sign of breakdown is dehydration and collapse of the

stem-end. To retard moisture loss, fruits for marketing are washed and waxed as soon as possible after harvest. When kept in prolonged storage, the grapefruit is subject to chilling injury (peel pitting) at temperatures below 50º F (10º C). The degree of injury depends on several factors: the fruits on the outside of the tree are more susceptible than the fruits that have been sheltered by foliage. The use of preharvest growth regulators tends to reduce susceptibility, as does 100% relative humidity during storage. Preconditioning at 60.8º F (16º C) for 7 days before storing at 33.8º F (1º C) prevents injury. Lowering the temperature gradually after preconditioning is also beneficial, as is sealing the fruit in polyethylene shrink-film before refrigerating (Morton, 1987).

The United States Department of Agriculture now requires that imported citrus fruits be kept at 32º F (0º C) for 10 days or at 36º F (2.2º C) for 16 days after the fruit has been cooled down to the specified temperature (Morton, 1987).

The rigors of harvesting and handling grapefruit can result in development of conditions grouped under the category of physiological disorders. Other conditions can appear as a result of the interaction of fruit physiology and environmental conditions (Petracek, *et al*. 1995).

The maturity indices are either not available or not enforced especially for local market in most countries in the region, but in exporting countries as Egypt, Tunisia, Lebanon etc. one would assume that harvesting must be according to a strict maturity index for each type of citrus fruits. For local market, prices would have an impact, since early harvested fruits have a higher price. In many countries in the region, no standards for quality of fresh citrus fruits are used in local marketing (Kader, 1979).

1.2.10 Specification of grapefruit

Sudanese grapefruit is well known for its large size, excellent quality and good coloration (Khalil, 1985).

The grapefruit must be fully composed, compatible to the item, intact without infection or damage and valid for consumption, clean and free of any odd material apparent on the surface, free of any odd odor or taste, free of unnatural excessive moisture on the surface, the diameter must not be less than 70mm, and the minimum juice content not less than 35%.According to these specifications grapefruits are classified into; extra class fruits , class1 (A) fruits, class2 (B) fruits, and class3 (C) fruits. The fruit size is determined by measuring the largest part of the cross section, these grades the grapefruit to large size (diameter above 120mm), medium size (diameter 108-119mm) and small size (diameter 70- 107mm)**,** (Sudanese standards and Metrology Organization, 2007). The standard specification of total soluble solids is 9 Brix, (US/ standard, 2012). The relationship between soluble solids and acidity is very important to determine if the fruit can be consumed as fresh market or processed. Soluble solids /acid ratios of 7.5 or 8.0 are good enough for fresh market grapefruit, but below 6.5 the fruit is good for processing. Besides soluble solids and acidity, fruit diameter must be greater than 70mm and contain at least 33% of juice (UNECE, 2004). Standard specification of the pH is 3.00−3.75, (US FDA/ CFSAN 2007), the standard specification of weight is 0.45kg as reported in Mexico where most cultivars had more than 450 g (0.45 kg) fruit weight (Becerra, and Medina, 2008).

1.2.11 Grapefruit benefits and uses

Grapefruit peel oil is used in aromatherapy and it is historically known for its aromatic scent (Worwood 1991).In Sudan, grapefruit is a major cash crop and an important component of diet because it is rich in vitamins (Sidahmed and Geneif,1984a). Grapefruit is a good source of vitamin C.

Grapefruit contains pectin, a form of soluble fiber that has been shown in animal studies to slow down the progression of atherosclerosis. Both blond and red grapefruit can reduce blood levels of cholesterol, and red grapefruit lowers triglycerides as well according to a study published in the Journal of Agricultural and Food Chemistry (GMF 2007). The effect of grapefruit juice with regard to drug absorption was originally discovered in 1989. However, the effect became well-publicized after being responsible for a number of deaths due to overdosing on medication (Bakalar 2006).

Other Uses

- Factory waste: the waste from grapefruit packing plants has long been converted into molasses for cattle,
- Seed hulls: After oil extraction, the hulls can be used for soil conditioning, or, combined with the dried pulp, as cattle feed. A detoxification process must precede the feeding of this product to pigs or poultry,
- Wood: Old grapefruit trees can be salvaged for their wood. The sapwood is pale-yellow or nearly white, the heartwood is yellow to brownish, hard, fine-grained, and useful for domestic purposes. Mainly, pruned branches and felled trees are cut up for firewood (Morton, 1987).

Medicinal Uses

An essence prepared from the flowers is taken to overcome insomnia, also as a stomachic and cardiac tonic. The pulp is considered an effective aid in the treatment of urinary disorders. Leaf extractions have shown antibiotic activity (Morton, 1987).

Chapter two

Materials and Methods

2.1. Location

This study was conducted during the winter season of the year 2012, at Shambat Sudan (lat. 15° 40 N, long 32° 32 E, and 380 m above sea level), at Food Research Center. The fruit samples of grapefruit (Foster and Duncan) were obtained from different orchards from River Nile State in the Sudan (lat 16°-22 N, long 30°-32 E). They were packed in carton boxes, and immediately transported and stored at Food Research Center in Khartoum, in refrigerator (12 C°).

2.2 Sample's number

100 Fruits were collected, 50 fruits of each cultivar, (Foster and Duncan); Nine fruits were taken randomly from each sample of cultivars (Foster and Duncan) for the study.

2.3 Methods

2.3.1 Fruit external characters

Fruit external characteristics were measured by standard method of measurements (Soule and Grierson, 1978).

2.3.1.1 Fruit Weight (Kg)

Weights of fruits were taken, three fruits each time to complete the total number of sample of each of the two cultivars (nine fruits of each cultivar) and weighted directly by scales (Plate .3) and divided the totally three to get the average weight of the individual fruit.

2.3.1.2. Fruit length

The length of the fruit was measured using Vernier caliper.

2.3.1.3Fruit width (diameter)

The width (diameter) of fruit was measured using Vernier caliper.

2.3.1.4 Peel thickness

Peel thickness was measured by using a graduate meter.

2.3.2 Fruit Internal characteristics

2.3.2.1 Number of seeds and segments

The number of seeds and number of segments were counted in each fruit after cutting it into two halves.

2.3.2.2. Calculation of juice percentage

Fruit juice was measured in mml using a graduate cylinder. The fruits were cut, quizzed and the amount of Juice was measured. The juice percentage was calculated using the following formula

Juice Percentage = juice amount ÷ fruit weight x 100

2.3.2.3 Total soluble Solids

Total soluble solids (TSS) were determined directly from the fruit juice using Kruss hand refractometer, (model HRN-32) (0-50% Brix) at 20C°, (Plate .4), three readings were taken from each sample of the two cultivars and the mean values were calculated and corrected according to refractometer chart.

2.3.2.4 Determination of pH

pH was determined directly from the fruit juice using pH Lyphan paper reels (Plate 5), two readings were taken from each sample of the two cultivars and the mean values were calculated.

2.3.2.5Flesh Firmness

Flesh firmness was measured by the Magnets and Taylor Firmness Tester, (D. Ballanf Meg. Co) (Plate 6), equipped with an 8 mm diameter plunger tip, three readings were taken from opposite sides of each fruit after the peel was removed. Flesh Firmness was expressed in kilogram per square centimeter.

2.4 Statistical analysis

Data collected were analyzed using SPSS computer program .The means of measurements were compared with a significance level of $P \leq 0.05$ was performed on the data.

Chapter three

Results

3.1 The segments number

3.1.1 The segments number of Duncan cultivar

The segments number of Duncan cultivar according to standard specification is 12 (Morton, 1987). The study results showed that the mean of the number of Duncan's segments was 11.2 (Table 3.1) and standard deviation was (± .97). The T test showed a significant difference between the number of Duncan's segments and the standard specification (STD) with P. Value = .043. So the specification of the number of Duncan's segment was not complied with the standard specification as shown in (Figure 3.1) and (Table3.2).

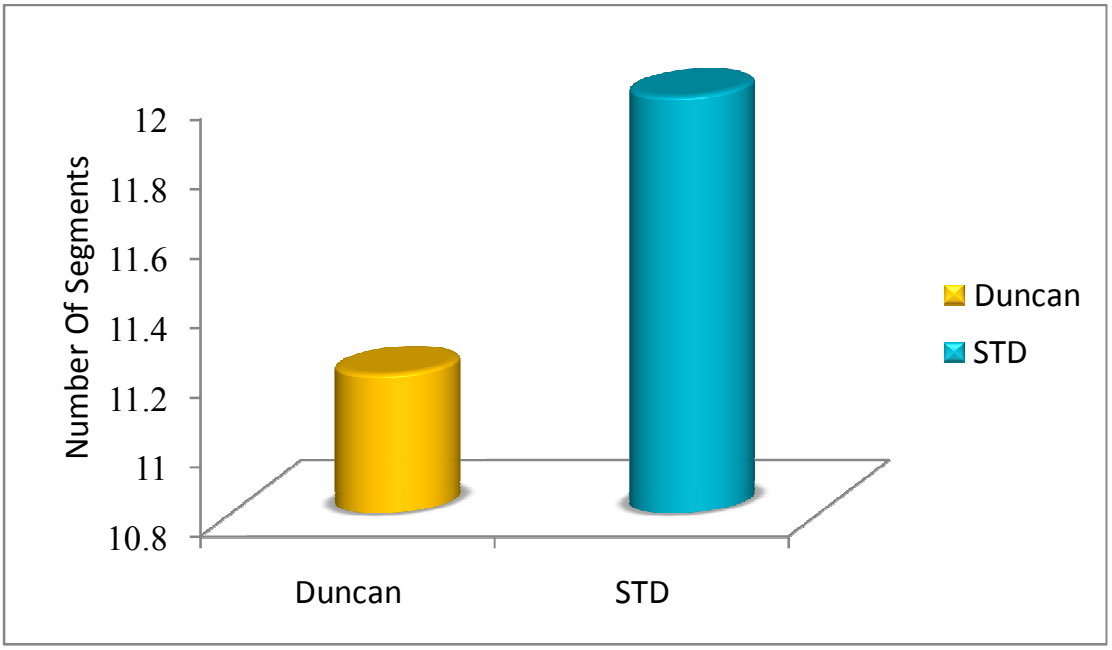

Figure 3.1 Mean of the number of segments in Duncan cultivar compared to standard specification of grapefruit

3.1.2 The segments number of Foster cultivar

The segments number of Foster cultivar according to standard specification is 13, (Morton, 1987). The study results showed that the mean of the segments number of Foster cultivar was 11.6 (Table 3.1) and standard deviation was (±1.32), the T test showed a significant difference between the segments number of Foster cultivar and the standard specification with P. Value = .016, so the specification of the number of Foster's segment was not complied with the standard specification as shown in (Figure 3.2) and (Table3.2).

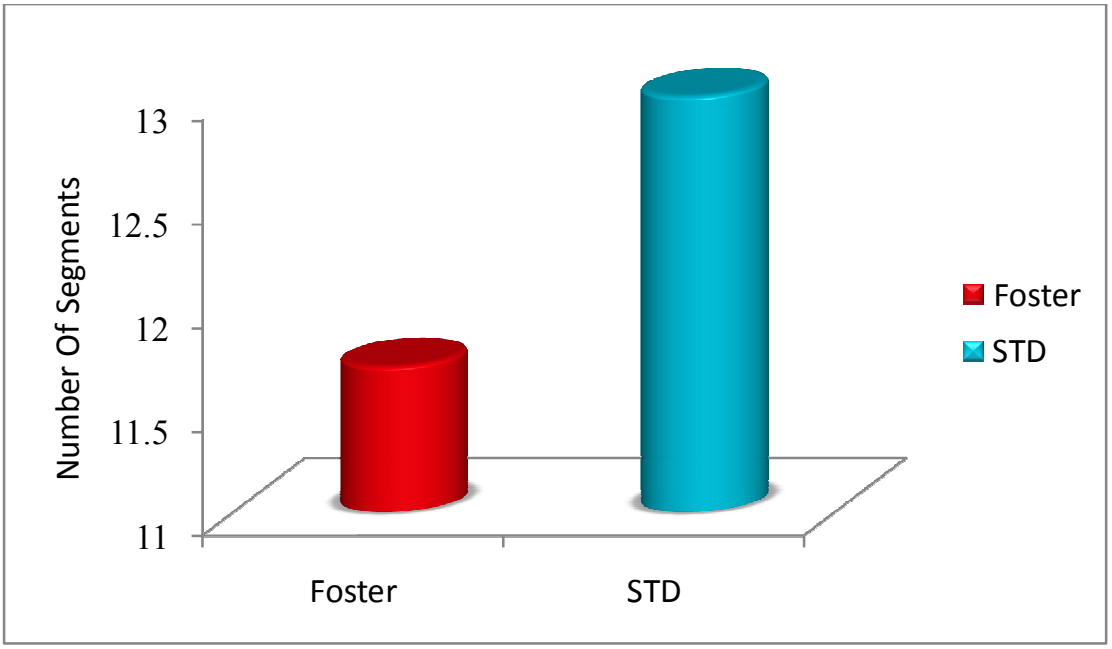

Figure 3.2, Mean of the number of segments in Foster, compared to standard specification of grapefruit

Table3.1.The means of Quality indices of fruit in Foster and Duncan cultivars

Quality indices	Mean of cultivars	
	Duncan	Foster
Number of Segment	11.2	11.6
TSS / Brix	11.7	11.3
pH	3	3.1
Juice content %	36.7	37.7
Number of Seeds	50.4	49.8
Fruit Weight/Kg	.38	.50
Fruit width /cm	9.2	10.2
Fruit Peel thickness/mm	11	9.4
Firmness	5.8	6.7
Fruit length	8.5	9.5

Table3.2. Comparison of Foster and Duncan cultivar to standard specification

Quality indices	cultivars	
	Duncan	Foster
Number of Segment	No Compliance	No Compliance
TSS	Compliance	Compliance
pH	Compliance	Compliance
Juice content%	Compliance	Compliance
Number of Seeds	Compliance	Compliance
Fruit Weight	No Compliance	Compliance
Fruit width	Compliance	Compliance

3.2 Total soluble solids (TSS)

3.2.1 TSS of Duncan cultivar

The Total soluble solids (TSS) of both Duncan and foster cultivars according to standard specification is 9, (US standard 2012) the study results showed that the mean of Duncan's TSS was 11.7 (Table3.1) and standard deviation of Duncan's TSS was (±.71), the T test showed a significant difference between Duncan's TSS and standard specification with P value =.000, but mean of Duncan's TSS higher than the standard specification, So the specification of Duncan's TSS complied with the standard specification as shown in (Figure 3.3) and (Table3.2).

3.2.2 TSS of Foster cultivar

The study results showed that the mean of Foster's TSS was 11.3 (Table3.1) and standard deviation of Foster's TSS was (± .6), the T test showed a significant difference between Foster's TSS and standard specification with P value =.000, but the mean of Foster's TSS was higher than the standard specification, so the specification of Foster's TSS complied with the standard specification as shown in (Figure 3.3) and (Table3.2)

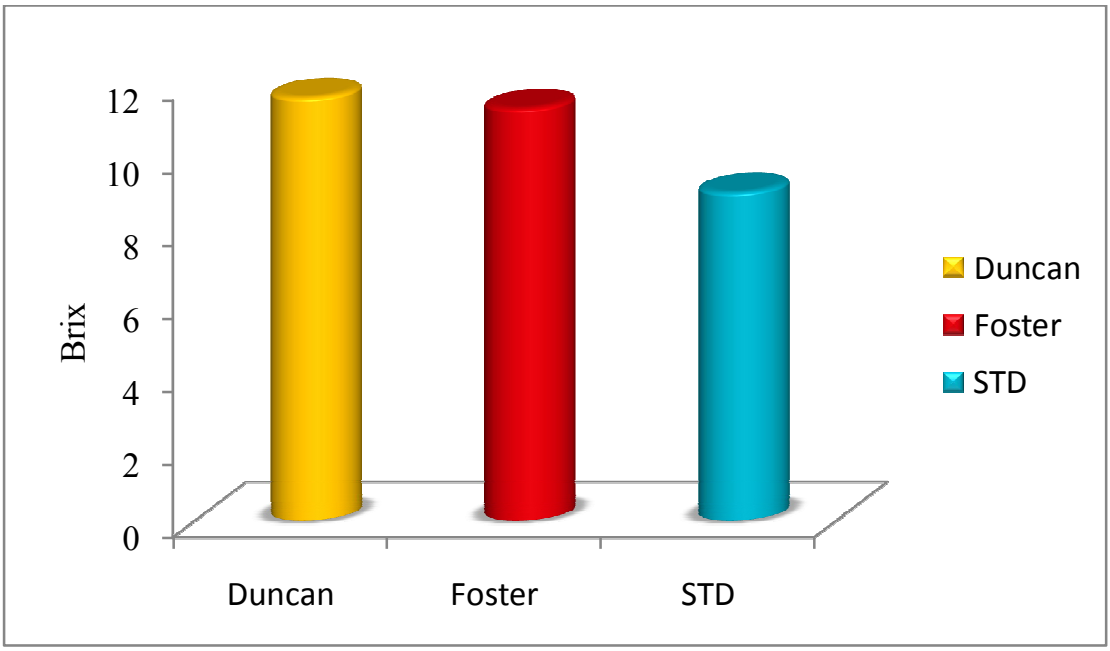

Figure 3.3 Mean of TSS in Foster and Duncan cultivars as compared to standard specification of grapefruit

3.3. pH

3.3.1 pH of Duncan cultivar

The pH of both Duncan and foster cultivars according to standard specification is 3 (US FDA/ CFSAN, 2007). The study results showed that the mean of Duncan's pH was 3 (Table3.1) and standard deviation of Duncan's pH was (±.00), The T test showed no significant difference between the Duncan's pH and the standard specification so the specification of Duncan's pH complied with the standard specification as shown in (Figure 3.4) and (Table3.2)**.**

3.3.2 pH of Foster cultivar

The study results showed that the mean of Foster's pH was 3.1 (Table3.1) and standard deviation of Foster's pH was (±.33), The T test showed no significant difference between the Foster's pH and the standard specification with P value =.347, so the specification of Foster's pH complied with the standard specification as shown in (Figure 3.4) and (Table3.2).

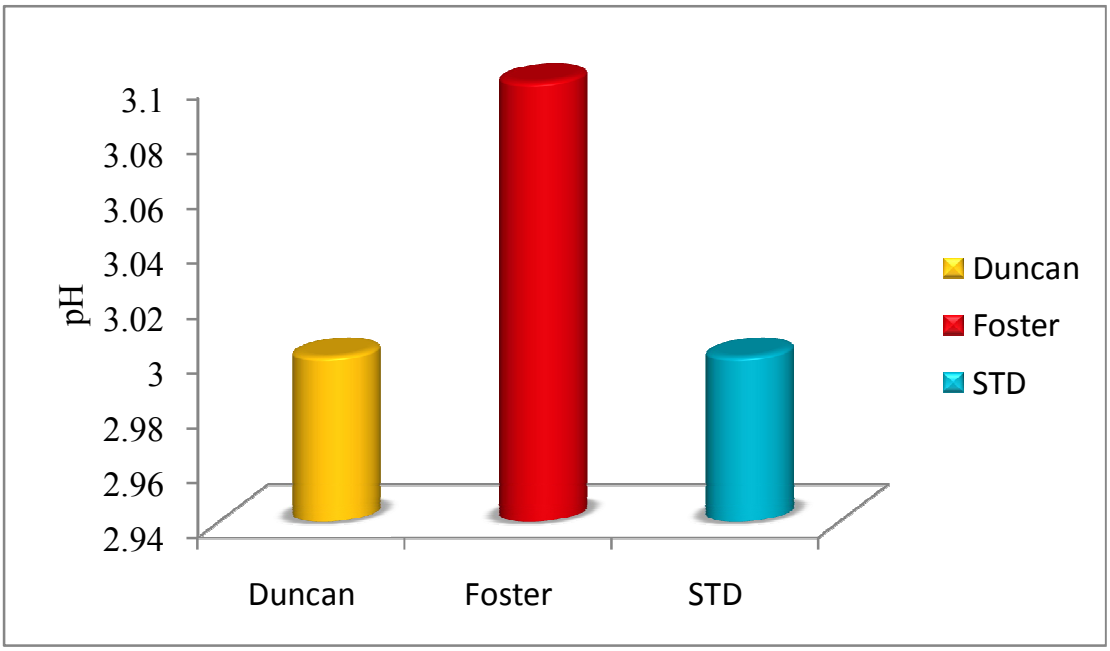

Figure 3.4 Mean of pH in Foster and Duncan cultivars as compared to standard specification of grapefruit

3.4 Juice content (% juice)

3.4.1 Juice content (% juice) of Duncan cultivar

The content of juice % of both Duncan and foster cultivars according to standard specification is 35%. The study results showed that the mean of Duncan's juice content was 36.7 % (Table3.1) and standard deviation of Duncan's content of juice was (± 5.38). T test showed no significance difference between Duncan's content of juice and standard specification with P. Value =.374, but mean of Duncan's juice content was higher than the standard specification, so the specification of Duncan's juice content was complied with the standard specification as shown in (Figure 3.5) and (Table3.2).

3.4.2 Juice content (% juice) of Foster cultivar

The study results showed that the mean of Foster's juice content was 37.7 % (Table3.1) and standard deviation of Foster's juice content was (±6.4). T test showed no significance difference between Foster's content of juice and standard specification with P. Value =.231, but the mean of Foster's juice content was higher than the standard specification, so the specification of Foster's juice content complied with the standard specification as shown in (Figure 3. 5) and (Table3.2).

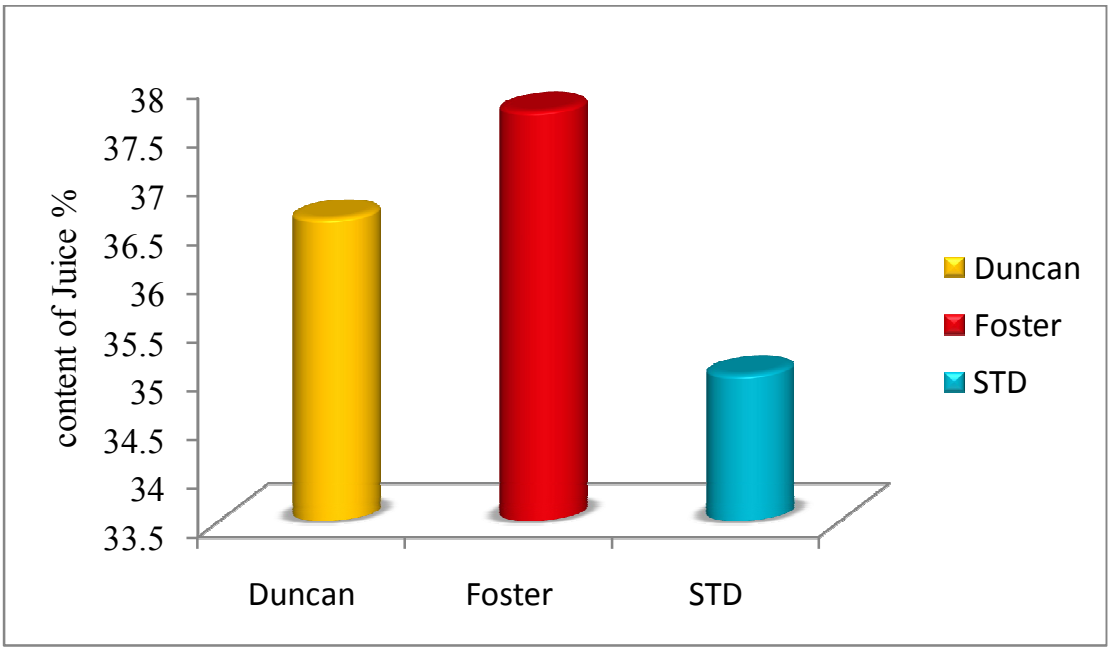

Figure 3.5 Mean of Juice in Foster and Duncan cultivars as compared to standard specification of grapefruit

3.5 Seeds Number

3.5.1 Seeds number of Duncan cultivar

The Seeds Number of both Duncan and foster cultivars according to standard specification is 50 (Morton, 1987).The study results showed that the mean of number of Duncan's seeds was 50.4 (Table 3.1) and standard deviation of number of Duncan's seeds was (±6.9). T test showed no significance difference between number of Duncan's seeds and standard specification with P. Value =.852, so the specification of number of Duncan's seeds complied with the standard specification as shown in (Figure 3.6) and (Table3.2)**.**

3.5.2 Seed's number of Foster cultivar

The study results showed that the mean of number of Foster's seeds was 49.8 (Table3.1) and standard deviation of number of Foster's seeds was (±10.8).The T test showed no significance difference between number of Foster's seeds and standard specification with P. Value .952, So the specification of number of Foster's seeds meets the standard specification as shown in (Figure 3.6) and (Table3.2)**.**

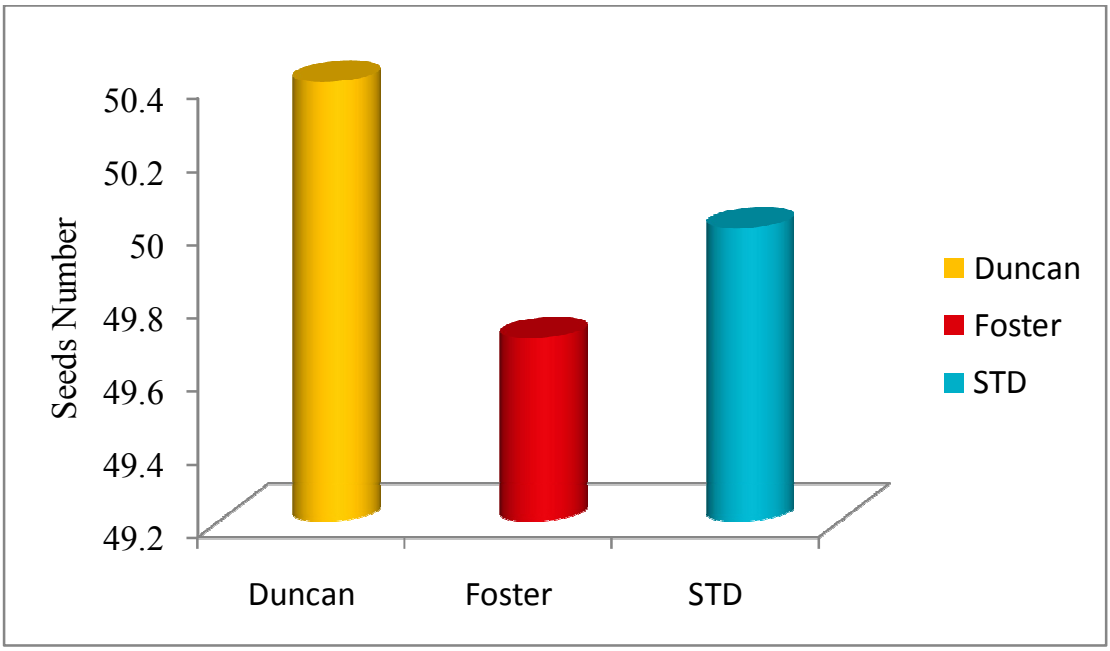

Figure 3.6 Mean of Number of Seeds in Foster and Duncan cultivars as compared to standard specification of grapefruit

3.6. Fruit Weight

3.6.1 Weight of Duncan Fruit

The Fruit weight of both Duncan and Foster cultivars according to standard specification is .45 Kg, (Becerra, and Medina, 2008). The study results showed that the mean of Duncan's Fruit weight was .38 kg (Table3.1) and standard deviation of Duncan's Fruit weight was (±.015). The T test showed a significant difference between Duncan's Fruit weight and standard specification with P value =.000, so the specification of Duncan's Fruit weight did not meet with the standard specification as shown in (Figure 3.7) and (Table3.2).

3.6.2Weight of Foster Fruit

The study results showed that the mean of Foster's Fruit weight was .50 kg (Table3.1) and standard deviation of Foster's Fruit weight was (±.02), the T test showed a significant difference between Foster's fruit weight and standard specification with P value =.000, but the mean of Foster's Fruit weight was higher than the standard specification, so the specification of Foster's fruit weight met the standard specification as shown in (Figure 3.7) and (Table3.2).

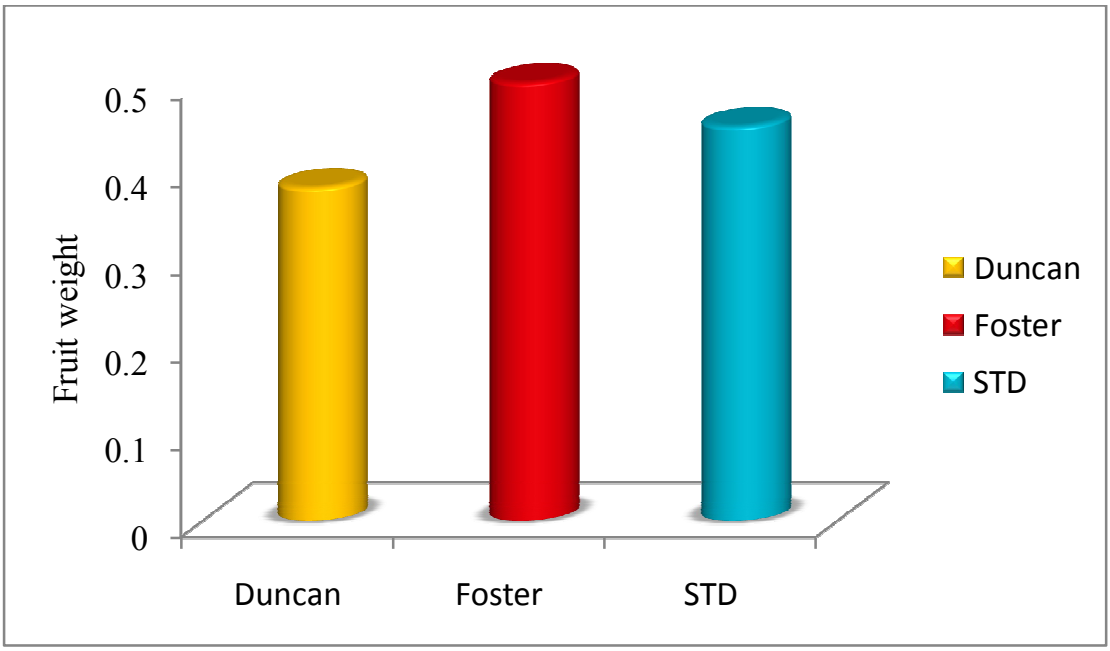

Figure 3.7 Mean of Fruit weight in Foster and Duncan cultivars as compared to standard specification of grapefruit

3.7 Fruit width (diameter)

3.7.1 Diameter of Duncan cultivar fruit

The Fruit diameter of both Duncan and Foster cultivars according to standard specification is 7 cm (Sudanese standards and Metrology Organization, 2007). The study results showed that the mean of Duncan's diameter was 9.2 cm (Table3.1) and standard deviation of Duncan's diameter was (±.53) the T test showed a significant difference between Duncan's diameter and standard specification with P value =.000, but the mean of Duncan's diameter was higher than the standard specification, so the specification of Duncan's diameter complied with the standard specification as shown in (Figure 3.8) and (Table3.2)**.**

3.7.2 Diameter of Foster cultivar fruit

The results showed that the mean of Foster's diameter was 10.2 cm (Table3.1) and standard deviation of Foster's diameter was (±.32) the T test showed a significant difference between Foster's diameter and standard specification with P value =.000, but the mean of Foster's diameter was higher than the standard specification, so the specification of Foster's diameter met the standard specification as shown in (Figure 3.8) and (Table3.2).

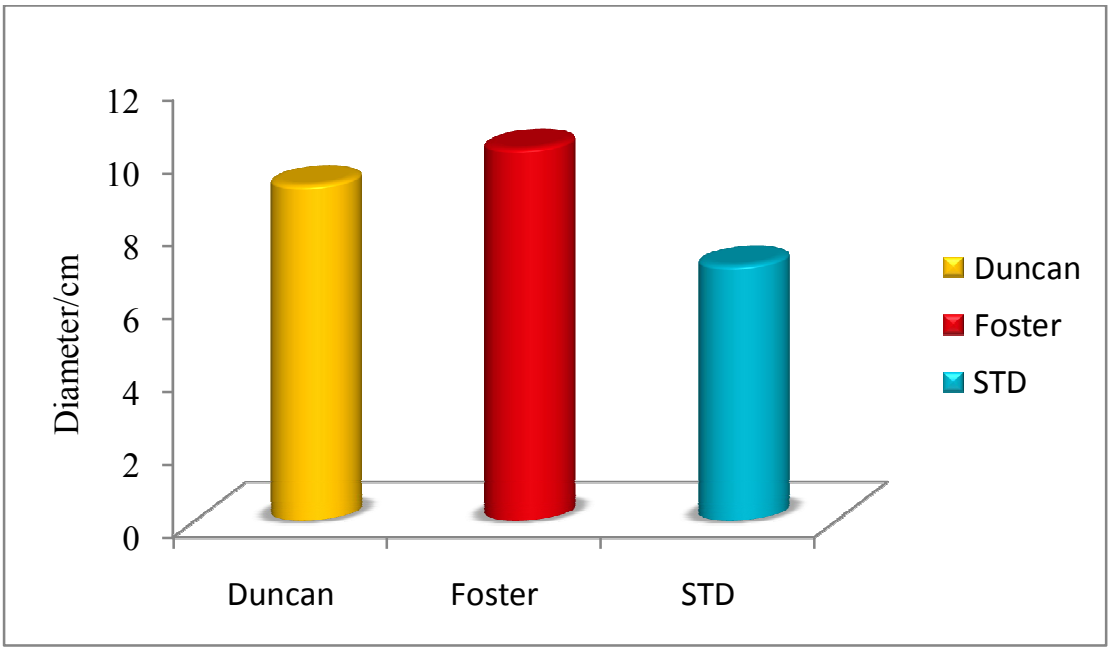

Figure 3.8 Mean of diameter (cm) in Foster and Duncan cultivars as compared to standard specification of grapefruit

3.8 Peel thickness

The mean size of peel thickness in Duncan/fruit was 11mm and in Foster/fruit was 9.4 mm (Table 3.1). T-test showed that there was a significant difference of Peel thickness between Foster and Duncan with P. value=0.03 as shown in (Figure 3.9)

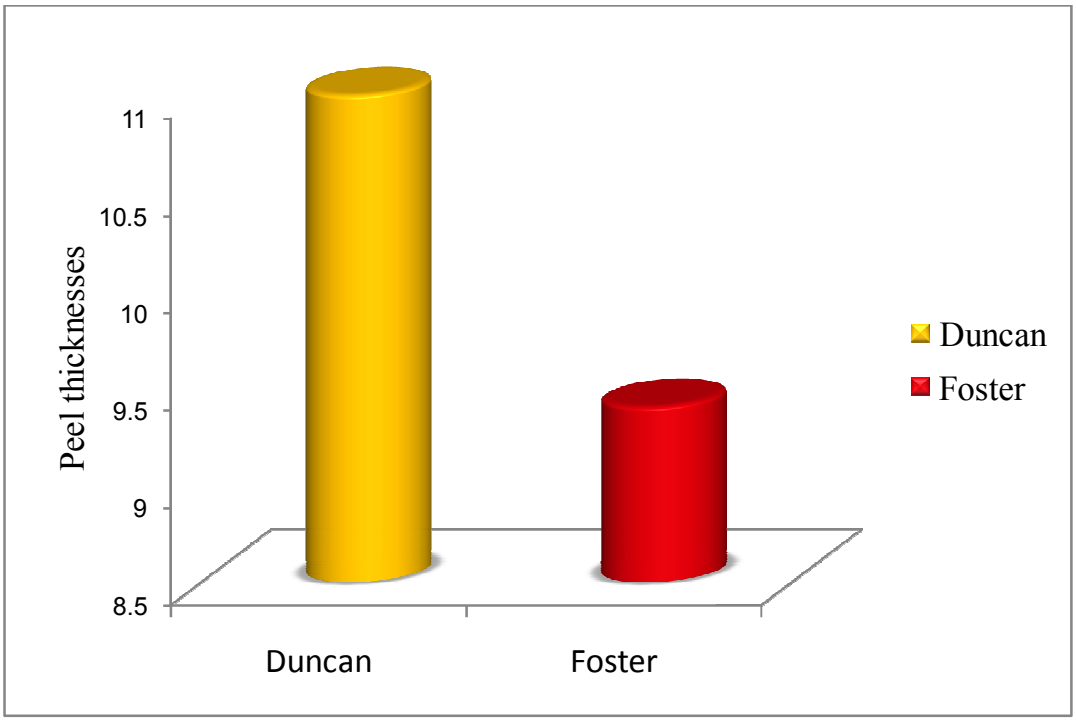

Figure 3.9 Peel thicknesses of Duncan and Foster cultivars

3.9 Firmness

The mean of firmness Duncan /fruit was 5.8 grams/ mm and in Foster /fruit was 6.7 grams/ mm (Table 3.1). T-test showed that there was a significant difference of firmness between Foster and Duncan with P. value= 0.04 as shown in (Figure 3.10).

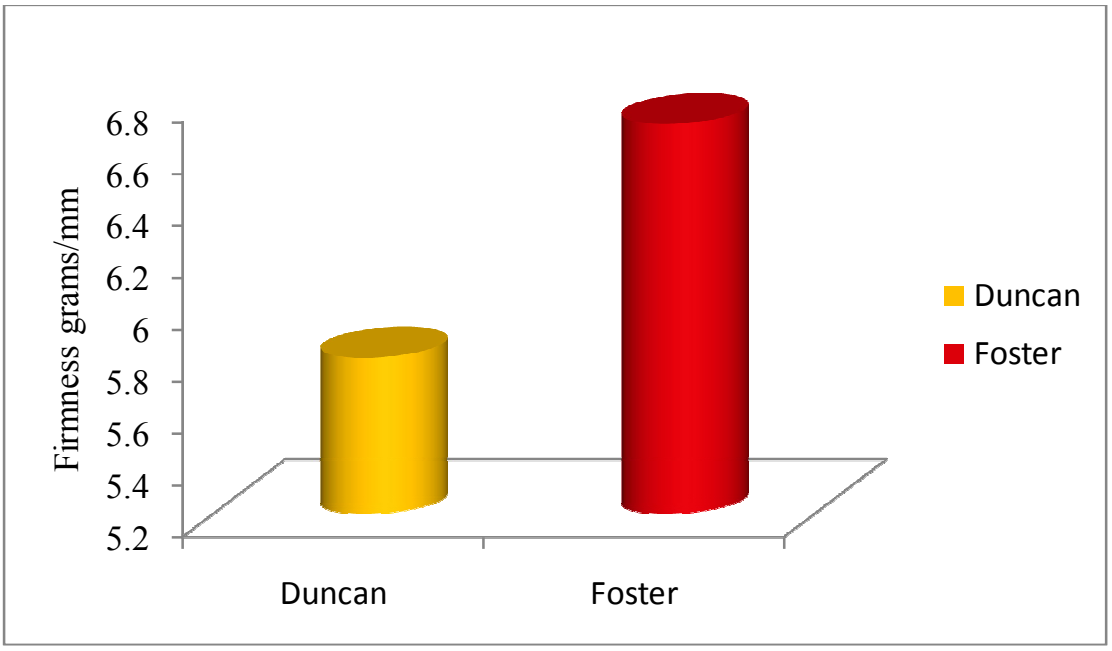

Figure 3.10 Firmness of Duncan and Foster cultivars

3.10 Fruit length

The mean size of length in Duncan /fruit was 8.5 cm and in Foster/fruit was 9.5 cm (Table 3.1). The T-test showed that there was a significant difference of Fruit length between Foster and Duncan with P. value=.000 as shown in (Figure 3.11).

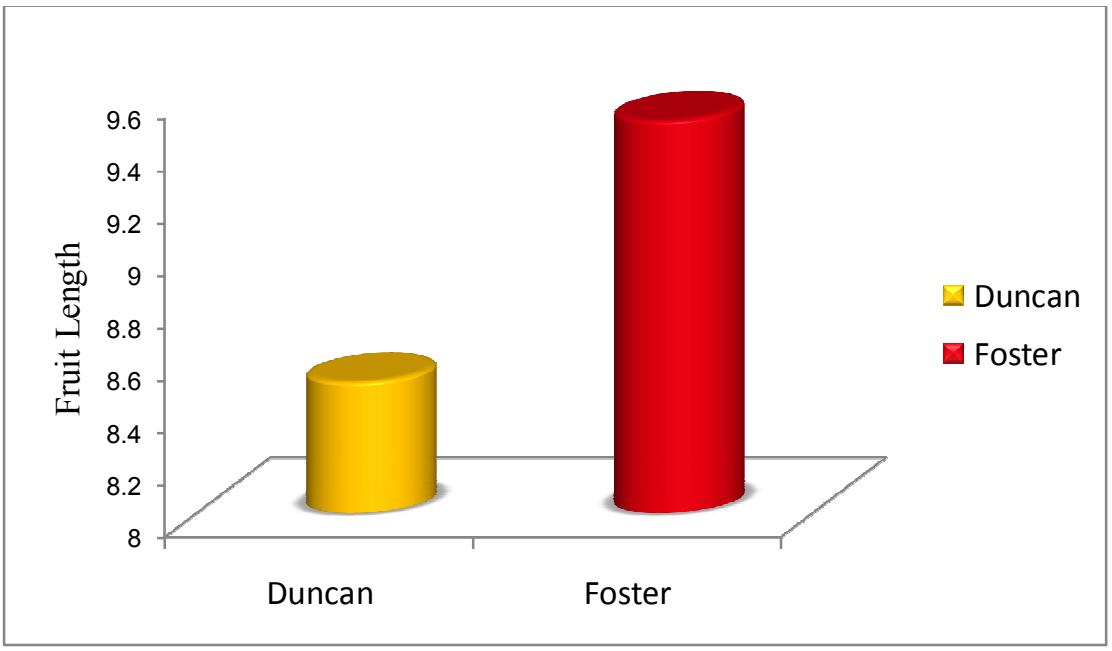

Figure 3.11 Fruit length of Duncan and Foster cultivars

Chapter Four

Discussion

4.1The segments number

As shown in figure 3.1the mean number of segments /fruit in Duncan cultivar was 11.2, it was low than standard specification, 12-14, according to Morton (1987). On the other hand, as shown in figure3.2 the mean number of segments /fruit in Foster cultivar was 11.6, it was low than the standard specification, 13-14, according to Morton (1987).

4.2Total soluble solid (TSS)

The Total soluble solids mean of Foster/fruit was 11.3 and Duncan/fruit was 11.7, in both cultivars, the total soluble solids are much higher than the standard specification, 9, according to (US/ standard, 2012) .The result of TSS of Foster/fruit and Duncan/Fruit was higher than that of Dubey, *et al*. (2013) who reported that the mean of TSS of Foster/fruit was 8.85 and Duncan/ fruit was 9.56. As well, these findings were higher than that of Hoogendoorn and Miller, (1986) who compared fruit samples collected from Florida as well as from other countries and reported that the total soluble solids (TSS) level in season (1984-1985) was 8.5 % in Cuban fruits, 9.4 % in both Mexican and Honduras fruits and 8.9 % in Florida fruits.

4.3 pH

The mean of pH level in Duncan/fruit was 3.00 and Foster /Fruit was 3.11 as shown in figure 4.4, both complied with standard specification 3.00−3.75 according to (US FDA/ CFSAN ,2007).

4.4 Juice content (% juice).

The mean juice content recorded in Foster/fruit 37.7% and Duncan/fruit was 36.7% (figure 3.5), both cultivars were higher than standard specification which was 35% according to (Sudanese standards and Metrology Organization, 2007).The juice content, agree with fruit from other countries such as Brazil; 37.6-39.7% (Donadio *et al.* 1996), Mexico; 24.1- 42.4% (Becerra and Medina,, 2008).

4.5 Seeds number

The mean number of seeds / fruit recorded was higher in Duncan /fruit 50.4(Figure 3.6), it was higher than the standard specification ,30-50, according to (Morton,1987),this result differs from that reported in new Delhi where the numbers of Duncan seeds/ fruit was < 32 seeds/fruit, Dubey, *et al.* (2013), while the mean of number of seeds/fruit in Foster ,49.8, was in agreement with the standard specification ,30-50, this result at par with those reported in New Delhi where the numbers of Foster seeds/fruit was 44 seeds/fruit, Dubey, *et al.* (2013).

4.6 Fruit Weight

The weight in Foster/ fruit was 0.50 kg, this is higher than the standard specification, 0.45kg, and disagrees with the weight in Duncan/ fruit 0.38 kg which is lower than Foster fruit and standard specification, reported in Mexico where most cultivars had more than 450 g (0.45 kg) fruit weight (Becerra, and Medina, 2008), this result was higher in Foster Fruit and lower in Duncan fruit than that of Dubey, *et al.* (2013) who reported that the mean of the weight in Foster fruit was 0.41 kg and Duncan fruit was 0.40 kg.

4.7 Fruit width (diameter)

The maximum mean of fruit width, 10.2 cm, was recorded in Foster fruit which was statistically different from Duncan fruit, 9.22 cm, but at par with Duncan fruit in terms of classification according to (Sudanese standards and Metrology Organization, 2007), which was classified as small size (diameter 7.0-10.7 cm). These findings are in accordance with results of Dubey, *et al.* (2013) who reported that the mean of width in Foster fruit was, 9.71cm, and in Duncan fruit was 9.74 cm.

4.8 Peel thickness of Fruit

The mean peel thickness of Duncan fruit was 11 mm (figure 3.9),it was higher than Foster fruit, 9.4 mm(figure 3.9) these findings were higher than that of Dubey, *et al.* (2013) who reported that the mean peel thickness of Duncan fruit was 6.63mm and Foster was 5.30 mm, furthermore, these findings were higher than that of Hoogendoorn and Miller (1986) who reported that the fruits from Florida and Mexico had the thinnest rind, with a mean of 5.3 mm, followed by fruits from Honduras and Cuba with rind thickness of 5.8 mm and 6.3 mm, respectively.

4.9 Fruit Firmness

The mean Firmness of Foster fruit was 6.7 grams/ mm; it was higher than Duncan fruit, 5.8, grams/ mm.

4.10 Fruit Length

The mean length of Foster fruit was 9.5 cm. It was higher than Duncan fruit, 8.5cm. These findings were in accordance with Dubey, *et al.* (2013) who reported that the maximum fruit length was 8.91cm, in Foster fruit followed by Duncan fruit, 8.56 cm.

These results confirm previous reports where variations in number of segments, total soluble solids, pH, Juice content, number of seeds, fruit weight, fruit width, peel thickness, fruit firmness and fruit length in different grapefruit cultivars were reported in different regions.

There are many factors causing these differences in this study in comparison to previous studies, these factors include:

- Environmental factors such as very high or low temperature, soil types, soil erosion, light and nutrient contents.
- Cultural practices as irrigation scheduling, fertilization and early and late harvesting.
- Management factors as poor storage and transportation, poor extension services.
- Economic factors as marketing system and poor financing.
- Policy factors insufficient agricultural, research and lack of coordination between education, research and extension.

Chapter Five

Conclusions and Recommendation

5.1 Conclusions

The Study determined the specification of grapefruit cultivars (Foster and Duncan) from River Nile State in Sudan and in comparision with standard specifications as determined by Sudanese Standards and Metrology Organization, US/ Standard and also as stated in the specification for each cultivar from previous studies.

The study revealed the following findings:

- Standard specification were determined for fruits of Foster cultivar and Duncan cultivar.
- These results confirmed previous reports in differences and similarities in quality indices which are number of segments, total soluble solid, pH, juice content, number of seeds, fruit weight, fruit width, peel thickness, fruit firmness and fruit length.
- Foster and Duncan cultivars have approximately the same standard specifications.
- Fruit of Foster cultivar has higher quality than fruit of Duncan cultivar.

5.1 Recommendations

Based on the study results the following recommendations are suggested**:**

- Since grapefruit do not continue to ripen after harvest, it is important to know the optimal maturity stage for harvest as you must know the indicators that determine by parameters such as external appearance, juice quantity and total soluble solids.
- Develop, activate and revise the laws that guarantee the quality of the fruits during storage and transfer from places of production to the place of consumption.

- Train producers to be acquainted with varieties, quality indicators and methods of modern transport and storage to ensure the safety of the product from damage.
- Cultivate new varieties of high economic value adapted to the environmental conditions prevailing in Sudan.
- Open new markets outside of Sudan and promote grapefruit consumption.
- Encourage investors to invest in grapefruit food processing and cosmetics.
- Continue research in the field of standards specification to reach the ranks of developed countries in this field.
- Modernize marketing, packaging and handling the fruits of grapefruit to maintain high quality.

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Appendices

Number of segments, TSS, pH, Juice content and number of seeds in fruit of Foster cultivar

No/sample	NO/ Segments	TSS	pH	Juice content %	NO / Seeds
1	12	12	3	35.19	54
2	10	11	3	36.53	58
3	12	10.5	3	40.38	59
4	11	12	3	37.25	53
5	12	11	4	46.07	68
6	10	11	3	24.11	54
7	13	11	3	42.55	59
8	11	11	3	42.55	50
9	14	12	3	35.10	51

Fruit Weight, Diameter, Peel thickness, Firmness and Length in fruit of Foster cultivar

No /sample	Weight kg	Diameter /cm	Peel thickness /mm	Firmness/ grams/ mm	Length/ cm
1	.52	10.20	0.9	7.6	9.21
2	.52	10.33	1	7.1	9.12
3	.52	10.43	0.9	6.1	9.10
4	.51	10.02	0.9	5.8	9.75
5	.51	10.76	1.1	6.1	9.91
6	.51	9.80	1	6.1	9.83
7	.47	9.90	1	7.3	9.18
8	.47	9.78	0.9	7.6	9.33
9	.47	10.22	0.8	6.5	9.72

Number of segments, TSS, pH, Juice content and number of seeds in fruit of Duncan cultivar

No /sample	NO/ Segments	TSS	pH	Juice %	NO / Seeds
1	10	11	3	38.1	45
2	10	13	3	28.37	38
3	12	12	3	41.35	43
4	11	12	3	38.64	53
5	12	11	3	32.16	57
6	12	12	3	41.35	53
7	12	11	3	35.36	53
8	12	12	3	30.73	59
9	10	11	3	44.14	53

Fruit Weight, Diameter, Peel thickness, Firmness and Length in fruit of Duncan cultivar

No /sample	Weight g	Diameter /cm	Peel thickness /mm	Firmness/ grams/ mm	Length/ cm
1	0.37	9.17	1.1	7.5	8.74
2	0.37	9.0	1.2	5.3	8.72
3	0.37	9.34	1.5	7	8.4
4	0.37	9.13	1	6.3	8.5
5	0.37	8.19	1	5.8	8.4
6	0.37	9.55	1	5	8.7
7	0.41	9.45	1	5.6	8.75
8	0.41	9.05	1.2	5	7.24
9	0.41	10.18	0.9	5	8.9

(Plate .1) Duncan cultivar

(Plate .2) Foster cultivar

(Plate .3) the scales

(Plate 4) Kruss hand refractometer, (model HRN-32)

(Plate 5) pH Lyphan paper reels

(Plate 6) Magnets and Taylor Firmness Tester