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Effect of Different Storage Conditions and Packaging Material on Microbial Characteristics and Physical Attributes of Sudanese Red and White Guava Cultivars (*Psidium Guajava L.*)

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Abstract: This study was conducted to evaluate the microbial characteristics and physical attributes of red and white guava fruit as affected by storage period, temperature, and packaging materials. Red and white flesh guava were divided into four groups each one of them was packed in Poly Venial Chloride (PVC) and polyethylene then were stored at room temperature (20 C^0) and refrigeration (4^0C) temperature for 7 days. Different analyses for guava samples were conducted including microbiological (Total Viable Bacterial Count (TVBC), *E. coli* and *Staphylococcus aureus*, physicochemical (pH and firmness). There were Significant ($P \leq 0.05$) differences in TVBC among guava samples. Sample packed in PVC recorded the lowest TVBC of (1.20 $\log_{10}$cfu/g) as compared to samples packaged in polyethylene bag (1.26$\log_{10}$cfu/g). It worth mentioning that, all guava cultivars in different packaging materials stored at different storage temperatures were *E. coli* and *Staphylococcus aureus* free. Samples store at refrigeratorion maintained higher in pH-value than these stored at room temperature No significant ($P \leq 0.05$) differences in firmness of guava by packaging materials and differences temperature. The highest firmness was 1.02 inch recorded for white flesh guava packed in PVC stored at refrigeration. Therefore, using PVC package at refrigeration temperature is more appropriate for guava cultivars. Safety (free of pathogenic *E.coli* and *Staphylococcus aureus*), better physical properties of guava fruits were maintained throughout the storage period. Therefore, the results concluded that, PVC is the best packaging materials for guava fruit and (4°C) is the best temperature for storage.

Keywords: Quality, guava, physical, microbial, polyethylene and PVC

1. Introduction

Sudan has a great potential to produce a good quality fruits and vegetables. This is because of it's large areas of fertile soil, abundant amount of water from rivers, rains and underground source, suitable wide range of climate which allow variability of fruits (Basheer and Imam, 2010). One of the important fruit in Sudan is guava (*Psidium guajava L.*) which belongs to the family *Myrtaceae*. Nowadays, with consumers' health awareness and the need to intake foods with low fats, free cholesterol and low salt guava is a good choice. The guava fruit is an excellent source of vitamin C and pectin with low energy (66cal/100g). The fruit is also rich in mineral like phosphorous, potassium, calcium and iron as well as other vitamins like niacin, panthotenic acid, thiamin, riboflavin and vitamin A (Mitra and Bose, 2001). There are four clones of guava in Sudan namely: Shendi (white pulp), Pakistani (white pulp), Gunib (red pulp) and Singa (white pulp) as stated by Elhassan (2016). Huge losses occur in the horticultural crops due to the poor post-harvest practices. Losses range between 30%-40% (Abdalazeez, 2005).Cooling Temperature and packaging materials are the important two factors which affect guava quality (Marsh and Bugusu, 2007). Therefore, product should be cooled as soon as possible after harvest to protect quality and extent shelf life (PFS, 2005). One the other hand, cooling temperature, it consider one of the most important factor in maintaining product quality in term of: microbiological, physical and chemical attributes via reducing the respiration rate as well as reducing growth of spoilage microorganisms and bacterial growth rate (Abdalazeez, 2005). Cooling maintain the sensory characteristics of fruit color, taste, flavor and texture (Roura *et al.*, 2000). Packaging materials play an important role in preserving and identifying the food product in addition to facilitating handling and commercializing via providing messages about product attributes to consumer, maintain the food safety and prevent contamination, and can also product promotion (Mersiowsky *et al.*, 1999). Polyethylene and Poly Vinyl Chloride (PVC) are the common materials used for packaging the fruits. Polyethylene, often called polythene, is probably the plastic most well known to the consumer and is used in greater volume worldwide than any other plastic (Risch, 2009). Polyethylene is still the most dominant food packaging plastic due to its relatively low cost, easy processing, its range of versatile properties and the ease with which it can be processed into various packaging forms to maintain the fruit quality attributes (Mersiowsky *et al.*, 1999).

Poly Vinyl Chloride (PVC) is the acronym for polyvinyl chloride, which is a long-chain polymer produced by a free- radical polymerisation of vinyl chloride monomer (VCM). It is excellent to maintain

organoleptic properties for food, high clarity (allow high visibility), good preservation properties for fruit, low cost, easy processing and different designs are achievable (Geueke *et al.,* 2018).

Objective:

1. To determine the effect of different packaging materials (polyethylene and Poly Vinyl Chloride (PVC) on microbial attributes of guava throughout storage period.
2. To determine the effect of different packaging materials (polyethylene and Poly Vinyl Chloride (PVC) on physical characteristics of guava throughout storage period.
3. To determine the effect of different storage temperature (room and refrigerator) on the microbial characteristics and physical attributes of guava throughout storage period.

2. Materials and Methods

2.1 Materials

2.1.1 Raw materials

Fresh guava samples White (Shindi) and Red (Sinja) were purchased from the central Market for fruits and vegetables at Bahri, and transferred immediately in sterilized container to the National Food Research Center (NFRC). Packaging materials were purchased from (Super market at Bahri city). Chemical and reagents are of analytical grade.

2.2 Methods

2.2.1 Experimental design

Fresh guava (white and red) were washed by a clean and sterilized water and then were divided into two groups. Each group was packaged into two packaging materials (polyethylene and Polyvinyl Chloride Plastic (PVC)) and were stored at room temperature and refrigerated for one week (Appendix 1 and 2). Different analysis was carried out including microbial attributes and physical characteristics.

2.2.2 Microbiological analysis

Microbiological analysis Total Viable Bacterial Count (TVBC), *E.coli and Staphylococcus aureus* was carried out according to (Harrigan andMcCance, 1976).

2.2.3 Physical analysis

Physical analysis (pH and Firmness) was determined according to the standard method of the Association of Official Analytical Chemists (AOAC, 2005).

2.2.4 Statistical analysis

All the experiments were carried out in triplicates independent runs and obtained data were analyzed using Minitab Statistical Software for windows (MINITAB, 2012).

3. Results and discussion:

3.1 Microbial characteristics of white and red guava as affected by storage temperature and packaging materials during storage period

3.1.1 Total Viable Bacterial Count (TVBC)

Table 1 showed significant ($P<0.05$) differences in TVBC among guava samples. Samples packed in PVC recorded the lowest TVBC of (1.20 $\log_{10}$cfu/g) as compared to sample packaged in polyethylene bag (1.26$\log_{10}$cfu/g). Similar trend for samples stored at room temperature contained higher TVBC. Ahmed (2006) recorded that PVC can maintain fruit in good quality. Joshi (2017) found that, TVBC of white and red guava packed in polyethylene bags showed TVBC range of 1.34 - 1.30 $\log_{10}$cfu/g. Ahmed (2008) found that, guava sample packaged in PVC had 1.67$\log_{10}$cfu/g TVBC. Generally, TVBC of guava samples increased by extend storage period.

Table 1: TVBC log_{10}cfu/g of white and red guava as affected by the storage temperature and packaging materials during storage period

Storage Period (day)	Red flesh				White flesh			
	Room Temperature		Refrigeration Temperature		Room Temperature		Refrigeratorion Temperature	
	Poly	PVC	Poly	PVC	Poly	PVC	Poly	PVC
0ne	1.35[a] (±0.09)	1.20[b] (±0.02)	1.17[b] (±0.02)	1.14[b] (±0.03).	1.38[a] (±0.06)	1.26[b] (±0.20)	1.19[b] (±0.04)	1.16[b] (±0.07)
Three	1.37[a] (±0.08)	1.35[a] (±0.02)	1.30[a] (±0.02)	1.25[a] (±0.03)	1.40[a] (±0.06)	1.38[a] (±0.04)	1.36[a] (±0.03)	1.34[a] (±0.05)
Five	1.51[c] (±0.02)	1.49[c] (±0.28)	1.47[b] (±0.04)	1.43[b] (±0.03)	1.56[c] (±0.03)	1.54[c] (±0.03)	1.52[c] (±0.02)	1.50[c] (±0.01)
Seven	-	1.53[d] (±0.11)	1.50[d] (±0.04)	1.49[d] (±0.05)	-	1.56[c] (±0.06)	1. 53[c] (±0.07)	1.52[e] (±0.06)

Poly: Polyethylene
PVC: Poly Vinyl Chloride
Values are mean ± SD for replicate independent analysis
Means in the same column for the same storage temperature of each specific packaging type bearing the same superscript small letters are not significantly different (P ≥0.05).

3.1.2 *E.coli* of white and red guava as affected by the storage temperature and packaging materials during storage period

Data in Table 2, revealed that, all guava samples under investigation were *E.coli* free in accordance with the Sudanese standards (2003). The results was similar to that found by Mourad (2017) who found that white flesh guava packed in polyethylene stored at refrigerator temperature for one week was *E. coli* free. Moreover, Joshi (2017) and Ahmed (2006) not detected any *E.coli* in white and red flesh guava packed in PVC at refrigerator temperature.

Table 2: *E.coli* of white and red guava as affected by the storage temperature and packaging materials during storage period

Storage Period	Red flesh				White flesh			
	Room Temperature		Refrigerator Temperature		Room Temperature		Refrigerator Temperature	
	Poly	PVC	Poly	PVC	Poly	PVC	Poly	PVC
Day 0ne	Nil	Nil	Nil	. Nil	Nil	Nil	Nil	Nil
Day Three	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Day Five	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Day Seven	-	Nil	Nil	Nil	-	Nil	Nil	Nil

Poly: Polyethylene
PVC: Poly Vinyl Chloride

3.1.3 *Staphylococcus aureus* of white and red guava as affected by the storage temperature and packaging materials during storage period

Table 3 showed that, *Staphylococcus aureus* was not detected in white and red flesh guava under investigation during the storage period. Thus all samples were in accordance with SSMO (2003) standard, which recommends that fruit must be *Staphylococcus aureus* free. Mourad (2017) found that, *Staphylococcus aureus* was appeared in white flesh packed in polyethylene bag stored at (+4°C) at day seven. However, Joshi (2017) found no growth of *Staphylococcus aureus* in white guava and red guava packed in PVC at 4°C throughout the storage period.

Table 3: Staphylococcus aurues of white and red guava as affected by the storage temperature and packaging materials during storage period

Storage Period	White flesh				Red flesh			
	Room Temperature		Refrigerator Temperature		Room Temperature		Refrigerator Temperature	
	Poly	PVC	Poly	PVC	Poly	PVC	Poly	PVC
Day 0ne	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Day Three	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Day Five	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Day Seven	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil

Poly: Polyethylene
PVC: Poly Vinyl Chloride

3.2. Physical characteristics of white and red guava as affected by the storage temperature and packaging materials during storage period

3.2.1 pH- values

Table 4, illustrated that pH-values were significantly ($P<0.05$) affected by the storage period. Generally, samples store at refrigerator ion (4°C) maintained higher in pH- value than these stored at room temperature due to low microbial activities by low temperature. For example; guava sample store at refrigeratorion (4°C) had pH value of 6.46, while, those stored at room temperature recorded pH value of 6.00. Similar result was reported by Ahmed (2006) who found, pH-values reduction at temperature. However, samples packed in polyethylene bags reported lower pH-values, when compared to those packaged in PVC bags. For white types guava; samples packed in polyethylene had pH values of 6.00, whereas, samples packed in PVC had pH values of 6.2. On the other hand, for red types, samples packed in polyethylene bags had pH values of 5.92, whereas, samples packed in PVC had higher pH values of 6.10. Similar results were reported by Mohammed (2009) who found that, the pH of guava packed in PVC was 6.20 pH. Mourad (2017) reported that, the pH of guava packed in polyethylene bag was pH of 6.44.

Generally, during the storage period, a significant decrease ($P\leq0.05$) in pH values were observed. White guava packed in the polyethylene bag at initial pH value was 6.81, then, it decreased to reach 4.4 after one week of storage period. Similar observation was noticed for red guava packed in PVC. At initial pH value was 6.38, then, it decreased to reach 4.76 after one week storage period. Similar pH decreasing trend were recorded by Joshi (2017); Ahmed (2006) and Kumar *et al.,* (2012).

Table 4: pH of white and red flesh guava pulp as affected by the storage temperature and packaging materials during storage period

Storage Period (day)	White guava pulp				Red guava pulp			
	Room Temperature		Refrigeration Temperature		Room Temperature		Refrigeration Temperature	
	Poly	PVC	Poly	PVC	Poly	PVC	Poly	PVC
0ne	6.81^{a} (±0.02)	6.82^{a} (±0.04)	6.84^{a} (±0.02)	6.88 (±0.02)	6.70^{h} (±0.0.2)	6.71^{a} (±0.03)	6.73^{a} (±0.60)	6.74^{a} (±0.02)
Three	6.42^{a} (±0.03)	6.46^{ab} (±0.04)	6.49^{b} (±0.03)	6.58^{b} (±0.03)	6.35^{bc} (±0.20)	6.37^{b} (±0.12)	6.40^{a} (±0.02)	6.41^{a} (±0.20)
Five	6.21^{b} (±0.32)	6.22^{b} (±0.26)	6.23^{b} (±0.04)	6.24^{b} (±0.06)	4.15^{c} (±0.20)	4.17^{c} (± 0.08)	6.18^{c} (±0.10)	6.19^{c} (±0.26)
Seven	-	5.69^{d}	5.83^{a}	5.90^{d}	-	5.06^{c}	5.15^{c}	5.58^{d}

		(±0.12)	(±0.11)	(±0.12)		(±0.17)	(±0.12)	(±0.20)

Poly: Polyethylene
PVC: Poly Vinyl Chloride
Values are means ± SD.
Values are mean ± SD for replicate independent analysis
Means in the same column for the same storage temperature of each specific packaging type bearing the same superscript small letters are not significantly different (P<0.05).

3.2.2 Firmness of white and red guava as affected by the storage temperature and packaging materials during storage period

Referring to the result presented in Table 5 there were no significant (P≥<0.05) differences in firmness of both guava extending storage period. The highest firmness was 1.02inch recorded for white flesh guava packed in PVC stored at refrigeration (4°C). Un expectedly, while, the lowest firmness was 0.90inch, recorded for red flesh guava packed in polyethylene bag and stored at room temperature. Mohammed *et al.,* (2016) found that, white flesh guava packed in PVC and stored at refrgeratorion was firmness of 1.20inch firmness. Higher firmness for white flesh guava (1.24inch), packed in polyethylene bag (Mourad, 2017). Joshi (2017) showed that white and red flesh guava packed in polyethylene bag stored at 4°C was firm (1.26inch). In fact firmness of guava fruit was not affected by storage period. The firmness of guava fruit decreased throughout the storage period. Initial (day one) white flesh guava packed in polyethylene bag and stored at room temperature showed had firmness value of 0.98 inch, while, red flesh one which was packed in PVC bag and stored at 4°C had initial firmness of 0.94inch and decreased to 0.88 by storage period. These reduction could be attributed to the fact that, firmness of fruit decreased when the fruit tend to be softer due to starch conversion to sugar substance (Ahmed, 2008). ,

Table 5: Firmness of white and red flesh guava pulp as affected by the storage temperature and packaging materials during storage period

Storage Period (day)	**White pulp**				**Red pulp**			
	Room Temperature		**Refrigeration Temperature**		**Room Temperature**		**Refrigeration Temperature**	
	Poly	**PVC**	**Poly**	**PVC**	**Poly**	**PVC**	**Poly**	**PVC**
0ne	0.98[a] (±0.01)	0.99[a] (±0.06)	1.01[a] (±0.07)	1.02 [a] (±0.07)	0.90[a] (±0.05)	0.92[a] (±0.05)	0.93[a] (±0.20)	0.94[a] (±0.07)
Three	0.97[a] (±0.11)	0.98[a] (±0.01)	1.00[a] (±0.06)	1.01[a] (±0.03)	0.85[a] (±0.07)	0.90[a] (±0.07)	0.91[a] (±0.07)	0.93[a] (±0.4)
Five	0.96 [a] (±0.24)	0.97[a] (±0.26)	0.99[a] (±0.29)	1.00[a] (±0.29)	0.83 [a] (± 0.07)	0.87[a] (± 0.08)	0. 89[a] (± 0.77)	0.90 [a] (±0.24)
Seven	-	0.96[a] (±0.22)	0.98[a] (±0.13)	0.99[a] (±0.07)	-	0.86[a] (±0.08)	0.87[a] (± 0.07)	0.88[a] (±0.10).

Poly: Polyethylene
PVC: Poly Vinyl Chloride
Values are mean ± SD for replicate independent analysis
Means in the same column for the same storage temperature of each specific packaging type bearing the same superscript small letters are not significantly different (P<0.05).

4. Conclution and Recommendations

4.1 Conclution

Based on the results obtained in the present study, the following conclusions can be drawn:

- Significant (P<0.05) differences in TVBC among guava samples. Sample packed in PVC recorded the lowest TVBC as compared to sample packaged in polyethylene bag.
- All guava samples under investigation were *E.coli and Staphylococcus aurues* free

- No significant (P≥0.05) differences in firmness of guava by packaging materials and temperature conditions differences.
- As storage period progress, TVBC increased and in contrast firmness, ,and pH decreased.
- Therefore, using PVC package at refrigeration temperature is more appropriate for both red and white guava cultivars. Safety (free of pathogenic *E.coli* and *Staphylococcus aureus*), better physical properties of guava fruits were maintained throughout the storage period

4.2 Recommendations

- Recommended to packaging guava fruit in PVC bag.
- Recommended refrigerated guava sample in 4°C.
- More researches to be conducted on sensory characteristics nutritional values and functional properties of the guava beverages to explore their
- health benefits and consumer preferences.

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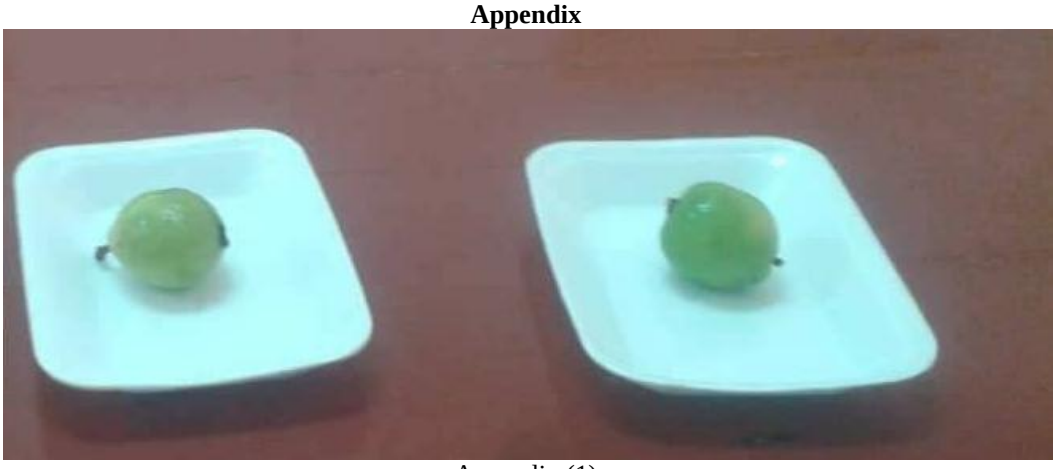
Appendix



Appendix (1)

Appendix (2)

Appendix (3)