Songklanakarin J. Sci. Technol.
44 (2), 466-473, Mar. - Apr. 2022

http://www.sjst.psu.ac.th

Original Article

Influences of storage conditions and duration on the chemical and sensory quality attributes of watermelon

Habtamu Tegen[1, 2*], Melkamu Alemayehu[1], Getachew Alemayehu[1], Ermias Abate[2], and Tadele Amare[2]

[1] *Bahir Dar University, College of Agriculture and Environmental Sciences, Bahir Dar, Ethiopia*

[2] *Amhara Region Agricultural Research Institute, Bahir Dar, Ethiopia*

Received: 30 June 2021; Revised: 28 August 2021; Accepted: 4 October 2021

Abstract

To satisfy customers, the quality of watermelon should not deteriorate throughout the value chain. Hence, this study aimed to evaluate the effects of storage alternative (plastic shade, zero energy cool chamber, naturally ventilated onion storage, and ordinary storage room), storage duration (1st, 2nd, 3rd 4th, and 5th-weeks), and variety (Crimson-sweet and Sugar-baby) sampled from three locations with factorial combinations in completely randomized design (CRD) with three replications. Storage condition, duration, variety, and location influenced the quality attributes. The plastic shade and ordinary storage room maintained better TSS (total soluble solids) compared to the others. Crimson-sweet maintained better TSS, acidity content, and overall acceptability during storage. Regardless of storage conditions, variety, and location, TSS decreased while pH increased with prolonged duration. TSS below the US standard of 8% manifested after the 4th-week of storage. The ordinary storage room maintained sensory qualities the best. The overall acceptability of stored fruits was ‘neither like nor dislike’ according to the panelists after the 4th-week in all storage conditions. It is concluded that watermelon has a shelf-life of one month. Therefore, we recommend plastic shade and ordinary storage room, Crimson-sweet variety, and Ribb and Woramit locations, for the watermelon value chain in Ethiopia.

Keywords: quality attributes, storage conditions, sensory evaluation, overall acceptability

1. Introduction

Watermelon (*Citrullus lanatus [*Thunb.*]* Matsum. and Nakai) is a warm-season crop in the Cucurbitaceae family (George, Darbie, & Kelley, 2017). Farmers cultivate it in a long frost-free season (Wehner, 2008). A challenge to its production and marketing in Africa is the lack of post-harvest technology (Dube, Ddamulira, & Maphosa, 2020). It is not suitable for long-term storage. The storability varies depending on variety and storage conditions (Department of Agriculture Forestry and Fishery [DAFF], 2011; Meister, 2004).

*Corresponding author
Email address: habitt2006@yahoo.com

The most crucial factors that affect the postharvest quality and storage life of fresh vegetables are temperature, relative humidity (RH), and ventilation. The desirable characters of watermelon for maintaining throughout the value-chain to satisfy the consumers are flesh color, flavor, taste, aroma, and texture (Wehner 2008; Zhou, 2011). Orzolek *et al*. (2010) explained that quality could be retained for 21 to 28 days after harvesting at storage temperatures from 8.5 to 13 °C and 85 to 90% RH. However, the optimum for storage and transportation is 10ºC with a shelf-life of 21 days to slow the degradation during storage. According to National Agriculture Research Institute [NARI] (2003), a shelf-life of 14 days was recorded at 15ºC storage temperature. Although the quality declines rapidly, there is a possibility of storing watermelon at ambient temperature. Too low temperatures below 10°C cause chilling injuries, decrease the redness of flesh, induce juice leakage, and favor *Alternaria* pathogen (Khater & Bhansawi, 2016; Meister, 2004; Wehner, 2008; Zhou, 2011). Temperature above 32°C causes internal flesh breakdown and increases decay. Yau, Rosnah, Noraziah, Chin, & Osman (2010) confirmed that watermelon could be stored at room temperature with 70-80% RH for two weeks, although the consumable quality prevails for one week after harvest.

Protecting watermelon from sunlight in the field and in storage is vital to minimize water losses, heat damage, and sunburn (DAFF, 2011). Sunburn is severe particularly at the ground spot area of the fruit, when there is a condition of upside positioning of the fruit (Motes, John, Warren, Jim, & Jonathan, 2017).

Postharvest loss is among the constraints of watermelon marketing. Thus the use of appropriate storage facilities is critical for reducing losses, and to sustain availability at affordable prices year-round (Ebiowe, 2013; Zhou, 2011). Watermelon can be stored in a wide range of structures, starting from simple shade up to sophisticated storage systems (Kiaya, 2014). Refrigeration however is capital intensive and mostly used in the developed countries. In the case of resource-poor countries like Ethiopia, it is necessary to develop inexpensive storage technologies using locally available materials (El-Ramady, Domokos-Szabolcsy, Abdalla, Taha, & Fári, 2015). Meister (2004) and DAFF (2011) confirmed shelf-life variability among the genotypes. Hence, it is felt vital to evaluate dominantly cultivated and consumed watermelon varieties in Ethiopia. Moreover, TSS, sugar content, rind and flesh thickness have been affected by cultivation environment (Edgar, Malla, Kevin, Crosby, & Avila 2020; Vasanthkumar, Shirol, Mulge, Thammaih & Aicrp 2012). Therefore, the current study aimed to evaluate the effects of storage conditions, duration, and variety on the chemical and sensory qualities of watermelon.

2. Materials and Methods

2.1. Description of the areas

Ribb, Woramit, and Koga were the fruit sampling areas that were cultivated in the 2019 irrigation season. The locations differ in altitude, temperature, and soil properties (Table 1 & Figure 1). Ribb, Woramit and Koga are located at 11°44',11°38′ and 11° 10' N latitude and 37°25', 37°10′, and 37° 2'E longitude, respectively. Meanwhile, the storage experiment was conducted at Woramit in Bahir Dar, Ethiopia.

2.2. Description of varieties

Crimson-sweet develops large sized fruit. It has light-green fruit with dark stripes, high sugar content and excellent shelf-life. It was released by Kansas State University, USA, in 1963. Sugar-baby represents the icebox type with round and dark fruit. Its flesh is bright red and firm with a super sweet taste. It has an average fruit weight of 3.5 to 5.5 kg (McCuistion, Elmstrom & Fred. 2005).

2.3. Description of the storage alternatives

Four alternative types of storage were used in the current study. Detailed descriptions and specifications of them are now given.

Table 1. Soil Physico-chemical properties in the production areas at 0-20 cm depth in 2019

Soil characteristic	Ribb	Woramit	Koga
pH	7.01	6.08	5.09
EC	35.4	32.9	31.70
OM(%)	2.51	3.116	3.121
N(%)	0.203	0.214	0.228
CEC	46.72	33.90	50.58
Available P (meq/100g soil)	29.81	24.011	2.98
Clay(%)	32	29	33
Silt(%)	59	53	55
Sand(%)	9	18	12
Texture	Silt-clay-loam	Silt-loam	Silt-clay-loam
Altitude(masl)	1774	1800	1960

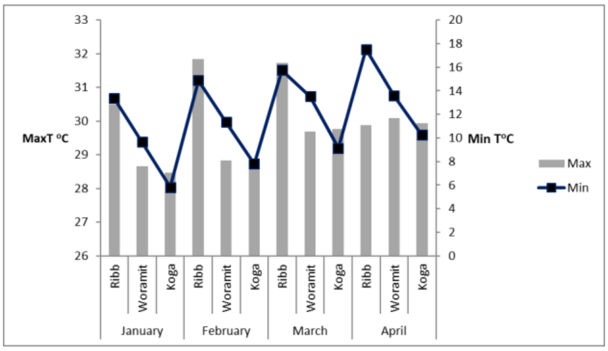

Figure 1. Temperatures on location during cultivation of watermelon in 2019

1. Plastic shade: This was modified to resemble the roadside marketplace storage of watermelon. It had 5m length, 2m width, and 4m height at the front side, and 3m at the backside. The whole frame was constructed of wooden materials. The shelves were raised 50 cm above the ground. The roof was constructed with a bamboo mat and covered with a white plastic sheet of 20 microns or 0.02 mm thickness. The three sides (excepting the front side) were covered with bamboo mats. The capacity to store fresh produce was about 1 ton.

2. Zero energy cooling chamber: The design had double walls made of clay bricks. The space between the walls was filled with sand. The dimensions of the outer wall were 1.50 m in length and width and 0.5 m height. The dimensions of the inner walls were 1.4 m length and width and 0.5 m height. The storage area was 1.2 m in length and width and 0.5 m height. The top part was covered with a bamboo mat combined with fiber sack. The whole chamber was covered with a shading curtain to protect it from direct sunlight. It had a capacity of 0.5 ton to store fresh produce.

3. Naturally ventilated onion storage: This was raised 50 cm above the ground for bottom ventilation. The dimensions were 3x3x5 m in length, width, and height, respectively. The bottom ventilation had two small doors for the inflow of fresh air and outflow of accumulated hot air. The wall was made from mud bricks and the roof was covered with 10 cm thick thatched grass. It had two shelves spaced to 50 cm distance. The storage has a window to load, unload and monitor. It has a capacity of 1.5 ton to store fresh produce.

4. Ordinary storage room: This was modified to represent the storage type used by the wholesalers at the central market of Addis Ababa, Ethiopia. It was 4 x 3 x 5 m in length, width, and height. The room was made with concrete brick walls and a corrugated iron roof with wood chip board ceiling. The fruit were stored in plastic crates. The capacity was 2.5 ton of fresh produce.

2.4. Experimental treatments and design

The treatments consisted of the four storage alternatives and two varieties produced in three locations. The treatments were arranged with 4 x 2 factorial combination in CRD with three replications.

2.5. Experimental procedures and data collection

Sample fruit with an average weight of 4.5 kg were collected from each location. An equal amount of 0.5 t fresh fruit were stored at each storage condition. The collected fruit were thoroughly washed using distilled water and diluted alcohol and stored in the respective treatments. Three fruit stored at each storage were randomly selected and analyzed for compositional changes and sensory quality at seven-day intervals.

The juice was extracted from sliced flesh using a High-Performance Commercial Blender. Palette digital refractometer ATAGO® PR-32α with a range from 0 to 32% was used to determine fruit TSS. The pH of juice was measured using a pH meter. Weight loss of fruit was determined, as it corresponds to the amount of water loss from the watermelon.

A panel of 15 evaluators was selected based on watermelon consumption experience, for evaluating the sensory qualities flesh color, flavor, taste, aroma, texture changes, and the overall acceptability on a 9-point hedonic scale (Epler, Chambers, & Kemp, 1998; Jaeger, & Cardello, 2009) (Figure 2).

2.6. Storage temperature and RH

Temperature and RH of the storage were monitored throughout the experimental period by using a digital hygro-thermometer. The readings were taken four times at three-hour intervals during the daytime starting from 1: 00 AM and once at midnight (Figure 3).

2.7. Data analysis

The analysis of variance (ANOVA) was conducted to assess the effects of storage condition, duration, and variety for each location with PROC GLM procedure (SAS Institute, 2002 version 9.0). After Bartlett's homogeneity of variance test, a combined analysis of variance by location was conducted using the PROC MIXED procedure of SAS. The storage, duration, and variety were considered as fixed factors while the location was considered a random factor. Whenever the ANOVA result showed significance ($P \leq 0.05$), the difference of means was further screened for significance using the Duncan multiple range test.

3. Results and Discussion

3.1. Effects of storage type and duration on the chemical qualities

The combined analysis of variance revealed that TSS, pH, and weight loss were significantly ($P<0.05$) influenced by storage, duration, variety, and location. These traits were also influenced by the interactions storage-vs.-variety, storage-vs.-duration, storage-vs.-location, variety-vs.-location, duration-vs.-location, storage-vs.-variety-vs.-duration, storage-vs.-variety-vs.-location, storage-vs.-duration-vs.-location and variety-vs.-duration-vs.-location (Table 2).

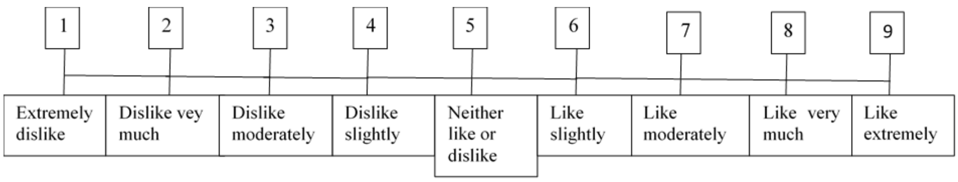

Figure 2. The 9-point hedonic scale for sensory evaluation of watermelon

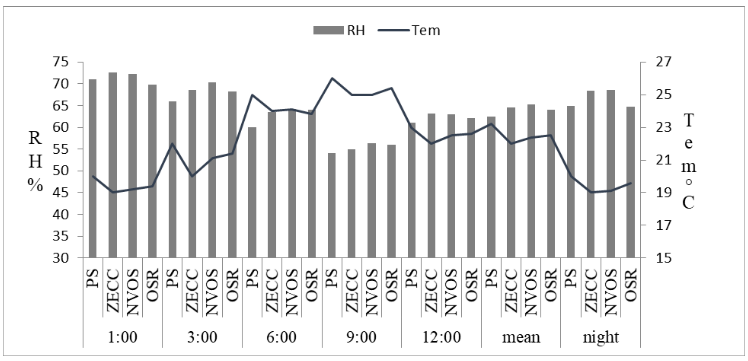

Figure 3. Mean temperature and relative humidity (RH) conditions in the storage structures. PS= plastic storage; ZECC=zero energy cool chamber; NVOS=naturally ventilated onion storage; OSR=ordinary storage room

Table 2. Significance level and variance analysis of the chemical quality attributes and weight loss of watermelon

Sources of variation	Traits			
	df	TSS	pH	Weight loss
Rep (L)	6	0.05^{ns}	0.01^{ns}	16799**
Storage	3	3.81**	0.02^{ns}	193726**
Variety	1	0.45*	7.80**	132157**
Duration	4	39.5**	1.31**	656388**
Location	2	2.06**	0.00^{ns}	2949529**
Storage-vs.-variety	3	1.70**	0.08**	160348**
Storage-vs.-density	12	0.44**	0.02**	7486**
Storage-vs.-location	6	2.77**	0.01^{ns}	233794**
Variety-vs.-duration	4	2.36**	0.12**	19094**
Variety-vs.-location	2	0.67**	0.08**	17829**
Duration-vs.-location	8	0.31**	0.02*	126471**
Storage-vs.-variety-vs.-duration	12	0.20**	0.01^{ns}	36150**
Storage-vs.-variety-vs.-location	6	10.59**	0.05**	47106**
Storage-vs.-variety-vs.-location	24	0.28**	0.02**	31801**
Variety-vs.-duration-vs.-location	8	0.26**	0.02*	4837**
Storage-vs.-variety-vs.-duration-vs.-location	24	0.29**	0.02**	18708**
Error	359	0.07	0.01	1434
CV(%)		2.99	1.58	17.40
R^2		0.94	0.88	0.97

**, * and ^{ns}:- highly significant (P≤0.01), significant (P≤0.05), and non-significant(P>0.05), respectively

Fruit stored under plastic shade and ordinary storage room maintained significantly better TSS and pH compared to the others. However, the fruit experienced large weight losses during the storage period. Higher TSS and weight loss but low pH were recorded for Crimson-sweet during the storage period. Watermelon produced at Woramit maintained higher TSS, while the highest water losses were for Ribb throughout the storage period when compared to Koga (Table 3). Relatively higher temperature and lower RH recorded in the plastic shade and in ordinary storage room (Figure 3) might contribute to maintaining TSS and pH better during the storage. A similar result was reported by Lokesha, Shivashankara, Laxman, Geetha, & Shankar (2019), in that the TSS increased in tomatoes under high storage temperature. Higher TSS and weight loss differences between varieties were due to genetic variability (Do Nascimento, De França Souza, De Cassia, & Da Silva 2019). Best watermelon TSS is obtained where the soil pH is between 6.0 and 6.8 (Jim, Rebek, Damicone, & Taylor, 2000). According to Maluki, Gesimba, & Ogweno (2016), the highest TSS of watermelon was recorded with the application of 50 and 100 kg P_2O_5 compared to zero. In this regard the optimum available soil P and pH were recorded at Woramit and Ribb rather than at Koga (Table 1). The comparative minimum temperature was scored at Koga during the cultivation period (Figure 1). According to Noh *et al*. (2013) temperature at 18 °C during fruit formation caused a significant increase in TSS by 11.5 % compared to 10.6 % at 14 ^{0}C. Moreover, although the CEC of the soil was high at Koga, its low pH (Table 1) affects the availability of nutrients negatively, with better TSS accumulation during cultivation.

The TSS of watermelon showed a decreasing trend while pH and weight loss increased during prolonged storage (Table 3). Yau *et al.* (2010) reported that TSS decreased from 9.13 to 7.43 and the pH increased from 5.10 to 5.34 during storage. Beaulieu and Lea (2007) reported that the pH of 5.25 at maturity increased to 6.51–6.79 during storage. The pH of a given fruit has an inverse relationship with organic acids in the juice. An increased pH in fruit during storage is therefore accompanied by the decrease in organic acids due to hydrolysis, which subsequently increases sweetness and decreases sourness (Singh & Sharma, 2017).

The TSS of varieties in the current study was generally below 10% (Table 3). In contrast, Kyriacou, Daniel, Colla, and Rouphael (2018) reported that most open-field watermelons attained 10 to 12 % TSS at full maturity. The stored fruit no longer complied with the US standard (< 8% in TSS) after the 4th-week of the storage. USDA (2011) reported that watermelons with good internal quality should not have a TSS content of less than 8%. Fruit juice acidity in the current study ranged from 5.5 to 5.8 in pH, which is predominantly derived from the presence of malic acid (Kyriacou *et al*., 2018).

The significantly highest weight loss in the current study was recorded for watermelon stored in plastic shade and ordinary storage room, which are associated with relatively high temperatures and low RH. A high temperature and low RH were persistent in these storage structures (Figure 3). According to Jim *et al*. (2000), the optimum storage conditions are 10-15^{0}C and 85-90% RH for watermelons, but none of the storage alternatives of the current study could reach this specification.

The weight loss during the storage observed in the current study was due to a high vapor pressure deficit, which accelerates the loss of water from fruits by transpiration (Khater & Bhansawi, 2016). Similarly, Xisto, Boas, Nunes, Federal, and Guerreiro (2012) reported that the increasing losses of weight, water, and soluble pectin were concurrent with a reduction in firmness due to the breakdown of cell structures.

Regarding the two-way interactions, both varieties stored in plastic shade and ordinary storage room maintained

Table 3. The effect of storage, variety, duration, and location on the chemical quality attributes and weight loss of watermelon

	Quality attributes		
	TSS	pH	Weight loss
Storage			
PS	8.94^{a}	5.96^{ab}	250^{a}
ZECC	8.62^{d}	5.98^{a}	220^{b}
NVOS	8.82^{c}	5.94^{b}	151^{c}
OSR	9.09^{a}	5.98^{a}	244^{a}
Significance	**	ns	**
Variety			
Crimson-sweet	8.90^{a}	5.82^{b}	236^{a}
Sugar-baby	8.83^{b}	6.11^{a}	197^{b}
Significance	*	**	**
Location			
Ribb	8.8^{b}	6.16	363^{a}
Woramit	9.1^{a}	5.97	51^{c}
Koga	8.8^{b}	5.97	235^{b}
Significance	**	ns	**
Duration			
1st-week	9.82^{a}	5.79^{e}	104^{e}
2nd-week	9.29^{b}	5.89^{d}	159^{d}
3rd-week	8.88^{c}	5.96^{c}	208^{c}
4th-week	8.48^{d}	6.03^{b}	256^{b}
5th-week	7.87^{e}	6.16^{a}	355^{a}
Significance	**	**	**
CV(%)	2.99	1.58	17.40

**, * and ns:- highly significant ($P \leq 0.01$), significant ($P \leq 0.05$), and non-significant($P>0.05$), respectively, Means with common letter in the same column do not differ significantly ($P>0.05$). PS= plastic storage; ZECC=zero energy cooling chamber; NVOS=naturally ventilated onion storage; OSR=ordinary storage room

high TSS compared to other storages. On the other hand, Sugar-baby variety stored in each storage maintained higher pH than the Crimson-sweet. Considerable weight loss was recorded for Crimson-sweet exceeding that of Sugar-baby in all storage structures (Figure 4).

Watermelon stored in the plastic shade and ordinary storage room maintained high TSS compared to the other storage alternatives regardless of the source location. Sugar-baby variety produced at all locations scored high pH while both varieties produced at Ribb scored high weight losses during the storage period. The highest weight loss was observed for watermelon produced at Ribb and stored in plastic shade and ordinary storage room. Relatively higher temperature and lower RH recorded in the plastic shade and ordinary storage room (Figure 3) favored the development of the highest TSS and weight loss (Figure 5).

3.2. Effects of storage structure and duration on the sensory qualities

The combined analysis of variance revealed that sensory qualities such as color, flavor, texture, aroma, taste, and overall acceptability were significantly ($P<0.05$) influenced by storage, duration, variety, and location. Only variety-vs.-location and storage-vs.-duration-vs.-variety interactions significantly influenced the sensory qualities (Table 4).

The sensory qualities and the overall acceptability of the stored fruit were influenced by the storage condition. Watermelon stored in naturally ventilated onion storage scored 6.02 to 6.69 mean on the hedonic scale, representing slightly liked. Crimson-sweet was moderately liked while Sugar-baby was neither liked nor disliked in all the sensory qualities. Fruit produced at Ribb were moderately liked while fruit grown at Woramit and Koga were neither liked nor disliked by the panelists (Table 5).

These sensory qualities decreased as storage time was prolonged. Immediately at harvest and one week after storage, all the sensory qualities were moderately liked by the panelists. At 2nd and 3rd-weeks, however, they were reduced and evaluated as slightly liked. Prolonging the storage time further to the 4th week caused the qualities to become drastically reduced, so they were neither liked nor disliked, and finally they were slightly disliked by the panelists at the 5^{t} week (Table 5).

The results of the current study are in line with the findings of Xisto *et al.* (2012) who reported intensity reduction of flavor, texture, aroma, and taste during storage. Watermelon flesh will tend to lose its red color when stored for a long time (Meister, 2004). The quality of a given vegetable, especially of a non-climacteric one, is highest at the time of harvesting Kyriacou *et al.* (2018) reported that

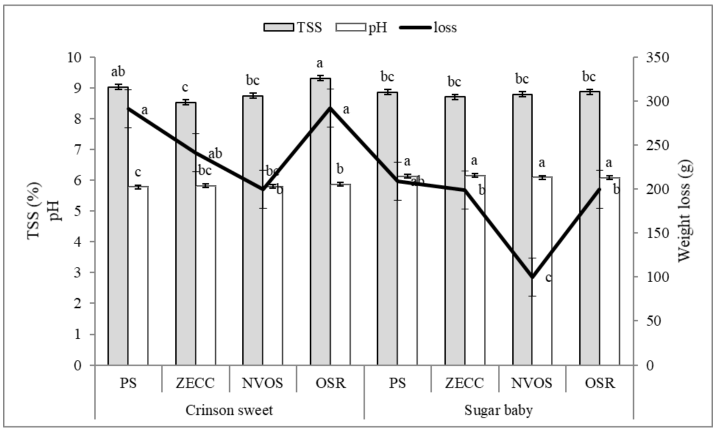

Figure 4. Effects of storage type and fruit variety on the chemical quality attributes and weight loss of watermelon. Different letters in each group indicate significant differences at $P \leq 0.05$. PS= plastic storage; ZECC=zero energy cool chamber; NVOS=naturally ventilated onion storage; OSR=ordinary storage room

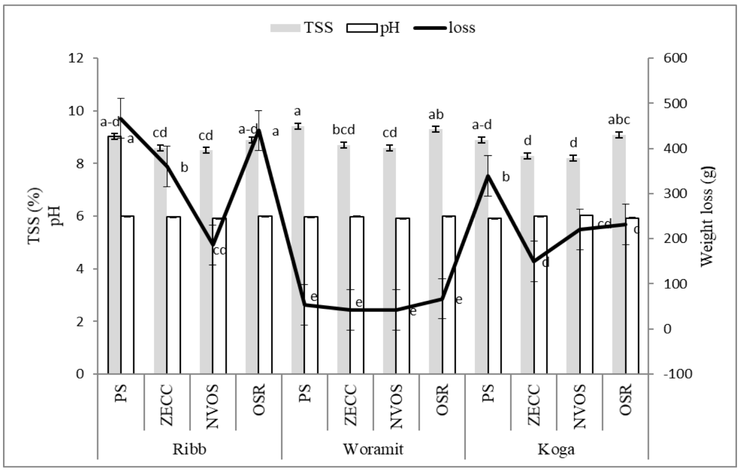

Figure 5. Effects of storage type, and location on the chemical quality attributes, and weight loss of watermelon. Different letters in each group indicate significant differences at (P≤0.05). PS= plastic storage; ZECC=zero energy cool chamber; NVOS=naturally ventilated onion storage; OSR=ordinary storage room

Table 4. Significance level and variance of the sensory quality attributes of watermelon during storage

Sources of variation	Traits						
	df	Color	Flavor	Texture	Aroma	Test	Overall acceptability
Storage	3	20^{*}	19^{*}	13^{*}	15^{*}	23^{*}	17^{*}
Variety	1	1021^{**}	635^{**}	550^{**}	543^{**}	613^{**}	650^{**}
Location	2	152^{**}	91^{**}	95^{**}	78^{**}	95^{**}	94^{**}
Duration	5	94^{**}	128^{**}	138^{**}	129^{**}	153^{**}	140^{**}
Storage-vs.-variety	3	2^{ns}	0.4^{ns}	0.2^{ns}	0.7^{ns}	1^{ns}	0.4^{ns}
Storage-vs.-location	6	3^{ns}	2^{ns}	2^{ns}	1^{ns}	2^{ns}	3^{ns}
Storage-vs.-duration	12	9^{ns}	6^{ns}	6^{ns}	7^{ns}	6^{ns}	5^{ns}
Variety-vs.-location	2	20^{*}	16^{*}	21^{*}	16^{*}	19^{*}	12^{*}
Variety-vs.-duration	5	60^{**}	54^{**}	59^{**}	53^{**}	56^{**}	55^{**}
Location-vs.-duration	7	7^{ns}	3^{ns}	5^{ns}	3^{ns}	5^{ns}	5^{ns}
Storage-vs.-location-vs.-variety	6	2^{ns}	1^{ns}	1^{ns}	1^{ns}	1^{ns}	1^{ns}
Storage-vs.-variety-vs.-duration	12	3^{ns}	3^{ns}	3^{ns}	2^{ns}	4^{ns}	3^{ns}
Storage-vs.-location-vs.-duration	18	4^{ns}	5^{ns}	4^{ns}	4^{ns}	5^{ns}	5^{ns}
Location-vs.-variety-vs.-duration	7	2^{ns}	2^{ns}	3^{ns}	3^{ns}	3^{ns}	2^{ns}
Storage-vs.-variety-vs.-location-vs.-duration	14	8^{ns}	5^{ns}	6^{ns}	5^{ns}	8^{ns}	6^{ns}
Error	696	3	2	2	3	3	2
CV(%)		28	27	28	28	28	27
R^2		0.55	0.54	0.53	0.52	0.56	0.55

*, ** and ns:- significant (P<0.05), highly significant (P<0.01), and non significant, respectively

continuous synthesis of lycopene reached its peak 7 days after harvesting at ambient conditions. Generally, maximum color saturation occurs during ripening. In contrast, Yau *et al.* (2010) reported that redness increased and intensified during storage. The decreasing trend of watermelon sugar content responsible for taste over a period was also reported by Lopez-Galarza *et al.* (2004). Similarly, DAFF (2011) reported that sugar content does not increase after harvest, while cell-well softness responsible for fruit texture decreases during storage (Khater and Bhansawi, 2016).

4. Conclusions

Watermelon quality attributes were affected by storage conditions, duration, variety, and source location. Plastic shade and ordinary storage room maintained better TSS compared to the other storage alternatives tested. Crimson-sweet maintained better TSS and acidity during storage. Fruit produced at Woramit and Ribb maintained better TSS and acidity content during storage. Watermelon TSS content was decreasing while pH had an increasing trend as the storage was prolonged, regardless of storage type, variety, and source location. Generally, in a breach of the US quality standard, below 8% TSS manifested after the 4th week of storage. Better sensory quality attributes were obtained for watermelon stored in ordinary room storage conditions. After the 4th week of storage, fruit stored in all storage conditions scored a 5 on the hedonic scale, which means 'neither like nor dislike' in the overall acceptability. The results of the current study confirm that watermelon can be stored for up to one month regardless of storage conditions, variety, and production location. Therefore, the plastic shade or an

Table 5. Mean hedonic ratings for the main effects of storage, variety and location on the sensory quality attributes of watermelon

	Quality attributes					
	Color	Flavor	Texture	Aroma	Test	Over all acceptability
Storage						
PS	5.98[bc]	5.56[b]	5.64[b]	5.56[b]	5.62[b]	5.67[b]
ZECC	5.92[c]	5.54[b]	5.61[b]	5.43[b]	5.37[b]	5.62[b]
NVOS	6.69[a]	6.18[a]	6.13[a]	6.02[a]	6.11[a]	6.11[a]
OSR	6.32[b]	6.04[a]	6.04[a]	5.96[a]	6.03[a]	6.17[a]
Significance	**	**	**	**	**	**
Variety						
Crimson-sweet	7.30[a]	6.69[a]	6.65[a]	6.53[a]	6.63[a]	6.76[a]
Sugar-baby	5.00[b]	4.88[b]	4.98[b]	4.87[b]	4.86[b]	4.95[b]
Significance	**	**	**	**	**	**
Location						
Ribb	6.87[a]	6.35[a]	6.38[a]	6.19[a]	6.32[a]	6.43[a]
Woramit	5.48[b]	5.15[b]	5.16[b]	4.95[c]	5.04[c]	5.19[c]
Koga	5.66[b]	5.47[c]	5.50[c]	5.55[b]	5.46[b]	5.55[b]
Significance	**	**	**	**	**	**
Duration						
0 (Initial)	7.55[a]	7.15[a]	7.36[a]	7.02[a]	6.97[a]	7.34[a]
1st-week	7.02[b]	6.84[a]	6.87[b]	6.76[a]	6.90[a]	6.89[a]
2nd week	6.44[c]	6.11[b]	6.19[c]	6.01[b]	6.19[b]	6.22[b]
3rd-week	6.02[cd]	5.57[c]	5.59[d]	5.41[c]	5.44[c]	5.78[b]
4th-week	5.54[d]	4.99[d]	4.96[e]	4.94[d]	4.88[d]	5.00[c]
5th-week	4.81[e]	4.27[e]	4.24[f]	4.19[e]	4.08[e]	4.21[d]
Significance	**	**	**	**	**	**
CV(%)	28.26	27.95	28.19	28.48	28.38	27.59

**:- highly significant (P<0.01). Means with common letter in the same column do not differ significantly (P>0.05). PS= plastic storage; ZECC=zero energy cool chamber; NVOS=naturally ventilated onion storage; OSR=ordinary storage room

ordinary storage room, Crimson-sweet variety, and Ribb and Woramit source locations, are recommended in the value chain of watermelons in Ethiopia.

Acknowledgements

The authors acknowledge Amhara Region Agricultural Research Institute and Bahir Dar University, College of Agriculture and Environmental Science for the provision of resources and logistics to conduct the study. We are also indebted to Adet Agricultural Research Center, Woramit Horticulture Research and Training Sub-center, and to the then Bahir Dar Food Science Research Center staff for their assistance during the execution of the experiments.

References

Beaulieu, J., & Lea, J. (2007). Quality changes in cantaloupe during growth, maturation, and in stored fresh-cut cubes prepared from fruit harvested at various maturities. *Journal of the American Society for Horticultural Science, 132*(5), 720–28. doi:10.21273/jashs.132.5.720

Department of Agriculture, Forestry and Fishery. (2011). *Watermelon* (*Citrullus Lanatus*) *production guidline*. Pretoria, South Africa: Author.

Dube, J., Ddamulira, G., & Maphosa, M. (2020). Watermelon production in Africa: Challenges and opportunities. *International Journal of Vegetable Science, 00*(00), 1–9. doi:10.1080/19315260.2020.1716128

Do Nascimento, T. L. De França Souza, F. De Cassia Souza Dias, R., & Da Silva, E. F. (2019). Watermelon general and specific combining ability. *Comunicata Scientiae, 10*(1), 132–140. doi:10.14295/cs.v10i1.2899

Ebiowe, K. (2013). Marketing margin and determinants of net return of watermelon marketing in Yenagoa Metropolis of Bayelsa State, Nigeria. *Journal of Experimental Biology and Agricultural Sciences, 1*(4), 241–47.

Edgar, C. Malla, S. Kevin, M. Crosby, & Avila, C. A. (2020). Evaluation of genotypes and association of traits in watermelon across two southern Texas locations. *Horticulturae, 6*(4), 1–11. doi:10.3390/horticulturae6040067

El-Ramady, É., Domokos-Szabolcsy, N., Abdalla, H., Taha, M., & Fári, G. (2015). Post-harvest management of fruits and vegetables storage. *Sustainable Agriculture Reviews, 15*(1), 65–151. doi:10.5962/bhl.title.152676

Epler, S., Chambers, E., & Kemp, K. (1998). Hedonic scales are a better predictor than Just-About-Right Scales of optimal sweetness in Lemonade. *Journal of Sensory Studies, 13*(2), 191–97.doi:10.1111/j.1745-459X.1998.tb00082.x

George, B., Darbie, G., and Kelley, T. (2017). *Commercial watermelon production, Bulletin 996*. Georgia: The University of Georgia.

Jaeger, R., & Cardello, A. (2009). Direct and indirect Hedonic scaling methods: A comparison of the Labeled

Affective Magnitude (LAM) scale and best-worst scaling. *Food Quality and Preference, 20*(3), 249–58. doi:10.1016/j.foodqual.2008.10.005

Jim, S., Rebek, E., Damicone, J., & Taylor M. (2000). *Watermelon production* (Tehnical report). Oklahoma, OK: Division of Agricultural Sciences and Natural Resources, Oklahoma State University.

Khater, G., & Bhansawi, A. (2016). Watermelon fruits properties as affected by storage conditions. *Misr Journal of Agricultural Engineering, 33*(1), 101–22. doi:10.21608/mjae.2016.98167

Kiaya, V. (2014). *Post-Harvest losses and strategies to reduce it* (Technical paper on post-harvest losses). Paris, France: ACF-international.

Kyriacou, M., Daniel, L., Colla, G., & Rouphael, Y. (2018). Watermelon and melon fruit quality: the genotypic and agro-environmental factors implicated. *Scientia Horticulturae, 234*(January 2021), 393–408. doi:10. 1016/j.scienta.2018.01.032

Lokesha, A. N. Shivashankara, K. S. Laxman, R. H. Geetha, G. A. & Shankar, A. G. (2019). Effect of high temperature on fruit quality parameters of con trasting tomato genotypes. International *Journal of Current Microbiology and Applied Sciences, 8*(03), 1019–1029. doi:10.20546/ijcmas.2019.803. 124

Lopez-Galarza, S., San Bautista, A., Perez, M., Miguel, A., Baixauli, C., Pascual, B., . . . Guardiola, L. (2004). Effects of grafting and Cytokinin-induced fruit setting on colour and sugar-content traits in glasshouse-grown triploid watermelon. J*ournal of Horticultural Science and Biotechnology, 79*(6), 971–76. doi:10.1080/14620316.2004.11511875

Maluki, M., Gesimba, R. M., & Ogweno, J. O. (2016). The effect of different Phosphorous levels on Yield and Quality of Watermelon {Citrullus lanatus (Thunb.) Matsumara & Nakai} grown in the Kenyan Coastal region. *Annals of Biological Research, 7*(5), 12–17.

McCuistion, Elmstrom, G.W. & Fred, R. (2005). Vegetable cultivar descriptions for north America. Water melon, lists 1954-2002. Retreived from https:// cucurbit.info/vegetable-newsletters-descriptions/ vegetable-cultivar-descriptions-for-north america

Meister, H. (2004). C*rops sample cost to establish and produce watermelon*. *UC Cooperative extension-imperial county vegetable crops guidelines*.

Motes, E., John, D., Warren, R., Jim, D., & Jonathan, E. (2017). *Watermelon production*. Oklahoma, OK: Oklahoma Cooperative Extension Service.

National Agricultural Research Institute. (2003). *Watermelon postharvest care and market preparation*. Georgetown, Guyana, Author.

Noh, J., Kim, M., Sheikh, S., Lee, G., Lim, H., & Seong, H. 2013. Effect of heat treatment around the fruit set region on growth and yield of watermelon **[***Citrullus lanatus* (Thunb.) Matsum. and Nakai**]**. *Physiology and Molecular Biology of Plants*, *19*(4), 509–514 doi:10.1007/s12298-013-0174-6.

Orzolek, M., Lamont W., Kime L., Bogash, S., County F., & Harper J. (2010). Watermelon production. Mississippi, MI: The Pennsylvania State University.

Singh, K., & Sharma, M. (2017). Review on biochemical changes associated with storage of fruit juice. *International Journal of Current Microbiology and Applied Sciences, 6*(8), 236–45. doi:10.20546/ ijcmas.2017.608.032

United States Department of Agriculture. (2011). *United States standards for grades of watermelon*. Washington, DC: Author.

Vasanthkumar, A. Shirol, M. Mulge, R. Thammaih, N. & Aicrp, P. (2012). Genotype x environmental interaction in watermelon (*Citrullus lanatus* Thunb.) genotypes for yield and quality traits. *Karnataka Journal of Agricultural Sciences, 25*(2), 248-252.

Wehner, C. (2008). Watermelon. In F. Nuez, & M. C. Jaime Prohens (Eds.), *Handbook of plant breeding, vegetable I* (pp. 381–418). New York, NY: Springer.

Xisto, A., Boas, E., Nunes, E., Federal, B., & Guerreiro, M. (2012). Volatile profile and physical, chemical, and biochemical changes in fresh cut watermelon during storage. *Food Science and Technology, 32*(1), 173–78. doi:10.1590/s0101-20612012005000020

Yau, W., Rosnah, S., Noraziah, M., Chin, L., & Osman, H. (2010). Physico-chemical compositions of the red seedless watermelons (*Citrullus Lanatus*). *International Food Research Journal*, *17*(2), 327–34. Retrieved from http://www.ghbook.ir/index.php

Zhou, W. (2011). *Demand for watermelon and application of aids models*. Florida, FL: University of Florida.