INFLUENCE OF STORAGE PERIOD ON THE RETENTION OF MACRO MINERALS IN JUICES OF DIFFERENT CITRUS CULTIVARS

Anjum Rashid, Zafar Iqbal, Muhammad Atif Randhawa, Azhar Ali, Atta Muhammad Arif, Sharoon Masih

Abstract— Citrus are nutritious fruits consumed as medicinal and food supplements, low in sodium, free from fat and cholesterol and rich in minerals. Minerals play an indispensible role in human body and essential for health maintenance. These remain stable under most of the conditions; however losses may occur during processing and storage. Minerals were extracted by wet digestion method and determined through Atomic Absorption Spectrophotometer. Concentration of calcium and magnesium consistently decreases while potassium and iron contents increase and sodium content remains almost stable during storage. Mineral content varied with citrus cultivars and storage period. Sodium content ranged from 5.404 (grapefruit) to 12.339mg/100mL, Potassium 483.190 (grapefruit) to 957.846 mg/100mL (Kinnow), magnesium 5.384 (mussambi) to 7.707 (Kinnow), calcium 0.545 (mussambi) to 0.773 (Kinnow), iron 0.381(Blood Red) to 1.310 (Kinnow), respectively. Mean (mg/100mL) vary from 6.755 (10th day) to 11.766 at 0 day for sodium, 733.333 (10th day) to 844.270 (20th day) for potassium, 6.083 (10th day) to 6.282 (30th day) for magnesium, 0.608 (10th day) to 0.640 at 30th day for calcium and 0.270 (0 day) to 1.467 at 45th day of storage for iron. Most minerals remain stable during storage except iron. Iron concentration increases during storage in all citrus juices.

Index Terms— atomin absorption spectrophotometer, citrus, mandarins, minerals, nutritional value

1 INTRODUCTION

Citrus is popular fruit grown throughout the world. It is produced in all the four provinces of Pakistan, Punjab being the leading province with over 95% share of the total produce [1], [2] (Pakissan.com, 2011; Khan, 2005). Kinnow is an important citrus cultivar popular in whole world for its peculiar aroma and taste. Pakistan is the 6th largest producer of kinnow and oranges in the world and has 95 % share in the total Kinnow production all over the world [1] (Pakissan.com, 2011). Higher post harvest losses in citrus fruits results in loses fruit quality [3] (Tariq et al., 2001). Only 1/3 of total citrus production is processed and juices are used as flavourings in beverages [4] (Farquer, 1996).

Citrus fruits are regarded as healthy food supplements and medicinal plants [5] (Abd Ghafar et al., 2010). These contain high quantity of water, carbohydrates, proteins and vitamins (A, B1, B2, C, D and E) [6] (Okwu & Emenike, 2006). Fruits are fat free, lower in sodium content and lack cholesterol (Economos, 1999). These fruits aid in lowering extent of cardiovascular disease and certain types of cancer. Oranges, grapefruits and lemons are most popular and widely consumed citrus fruits around the world [7] (Zvaigzne et al., 2009). Citrus juices have gained consumer acceptance due to their peculiar exotic aroma and color. Citrus juices contain bioactive compounds which act as antioxidant, anti-inflammatory, anti-tumor, anti-fungal and inhibitory activities against blood clot [8], [9], [10] (Garg et al., 2001; Kaur & Kapoor, 2001; Abeysinghe et al., 2007).

Consumption of fruit juices is beneficial for health due to higher amount of macro minerals [11] (Dosumu et al., 2009). Minerals are of immense significance in the diet; however these represent merely 4–6% bodyweight of individual [12] (Magaia et al., 2013). Macro elements are needed in amounts higher than 100 mg per day represent 1% or less of body weight [13], [14] (Insel et al. 2011; Imelouane et al. 2011). The essential macro elements include calcium, phosphors, magnesium, potassium, sodium, sulfur and chloride [12] (Magaia et al., 2013). Zinc, iron, copper, manganese, selenium, iodine and molybdenum are essential trace elements. Daily requirement of these minerals is generally less than 100 mg and contribute less than 0.01% of the bodyweight [14] (Imelouane et al. 2011).

Minerals present in citrus fruits help in lowering blood pressure and risk of stroke [6] (Okwu & Emenike, 2006). Inorganic elements Ca, P, Fe, Mg [15], [16] (Mamiro et al., 2007; Saka et al., 2007), K, Zn and Cl [17] (Nagy, 1977) have been found in citrus fruits. Potassium and nitrogen account for about 80% of the total minerals in citrus fruits [18] (Izquierdo & Sendra, 1993). These minerals play a vital role in the

- *Anjum Rashid is currently pursuing Ph.D degree program in Dairy Technology at University of Vetrnary and Animal Sciences, Pakistan, PH-+92-03324096412. E-mail: anjofst@yahoo.com*
- *Muhammad Atif Randhawa is currently working as Assistant Professor at National Inst. of Food Sci. & Tech. in University of Agriculture Faisalabad,Pakistan, PH-+92-03007677116. E-mail: author_name@mail.com*
- Zafar Iqbal *is currently working as Research Officer at Oilseeds Research Institute in Ayub Agri. Research Inst. Faisalabad, Pakistan, PH-+92-03066002629. E-mail: zafarft@yahoo.co.in*
- *Azhar Ali is currently working as Director Post Harvest Research Centre, in Ayub Agri. Research Inst. Faisalabad, Pakistan, PH-+92-03066002629. E-mail: phrc@yahoo.co.in*
- *Atta Muhammad Arif is currently pursuing Ph.D degree program in Dairy Technology at University of Vetrnary and Animal Sciences, Pakistan, PH-+92-03324096412. E-mail: anjofst@yahoo.com*
- *Sharoon Masih is currently working as Research Officer Food Technology Section, Post Harvest Research Centre, Ayub Agricultural Research Institute, Faisalabad-Pakistan, PH-+92-03457891960. E-mail: sharoon_uaf@yahoo.com*

maintenance of human health [19] (Schrimshaw, 1991). Orange fruits are excellent source of vitamins and minerals. Orange juice contains good quantity of minerals particularly phosphorus and calcium; however potassium is the predominant.

Human body require higher amount of macro minerals (potassium and sodium) for the maintenance of water, fluid and electrolyte balance in cells and help in transportation of nerve impulses [20], [21] (Worthington-Roberts, 2007; Wardlaw, 1999). Their deficiency lead to muscle cramps, mental confusion, loss of appetite and irregular heart beat [20] (Worthington-Roberts, 2007). Potassium helps muscles to contract and releases energy from protein, fat and carbohydrates during metabolism; lower the blood pressure and reduce the risk of stroke [22] (Joshipura et al., 1999). Sodium intake has linear relationship with hypertension in humans [23] (Dahl, 1972) so the concentration of sodium should be lower than potassium in foods. Magnesium is responsible for transfer of phosphate, stable nucleic acid structure and absorption of nutrients in intestine [24] (Falade et al., 2003). Calcium is essential in bone and teeth formation [21] (Wardlaw, 1999) and a deficiency of it causes rickets and osteoporosis [25] (Hunt et al., 1980). Iron is an integral part of the blood and responsible for electron transmission. Deficiency of iron results in anemia, fatigue and headache [24] (Falade et al., 2003).

Keeping in view, the nutritional and health benefits of minerals, the present investigation was planned to evaluate the mineral content of four important citrus cultivars grown commercially in Pakistan and to quantify the effect of storage on the retention of minerals in juices without addition of any preservative. Juice samples were stored at 5°C because this temperature usually prevails in commercial citrus juice industry.

2 Materials and Methods

2.1 Raw material: Different citrus species (Kinnow, Grapefruit, Blood Red and Musambi) were taken from local market. All the samples were stored at 5°C and were processed into fruit juice within a week. Fruits were washed in a tap water and then were peeled and divided into halves.

2.2 Fruit processing: Fruit juice was extracted using a lab scale citrus juice extractor (Moulinex T574, France) by applying method described by Karadeniz [25] (2004). Then samples were cooled with tap water and were stored at -20°C until analysis. Different citrus varieties were evaluated at 0, 10, 20, and 30 days of storage for mineral concentration.

2.3 Estimation of mineral contents: Samples of each fruit juice were digested by the wet ashing method for mineral content determination as described by Abulude et al. [26] (2007) using atomic absorption spectrophotometer. The minerals contents were monitored during storage of citrus juices at specific intervals.

2.4 Chemicals and standards: All chemicals used were of analytical grade, purchased from local suppliers of Merck and Sigma-Aldrich. The stock solution and the corresponding dilutions was made in deionized water and stored in dark places between the experiments, at refrigeration temperature.

2.6 Statistical Analysis: The data obtained was subjected to statistical analysis by using Completely Randomized Design (three factor factorial) and comparison of means was done by Duncan's Multiple Range Test [27] (Steel et al., 1997).

3 Results and Discussion

3.1 Sodium content: The statistical analysis (Table 1) revealed that the sodium of the citrus juices was significantly affected by storage period, treatment and the first order interaction between storage time and treatment. The sodium content was found to be highest at the initiation of storage period with mean value (8.15 mg/100ml) which is similar to mean at 30th day in T_2 while lowest (8.03 mg/100ml) at the 20th day which is statistically at par with mean value at 0 day in T_1 (Fig. 1). Among treatments, significantly higher sodium content was observed in T_2 (grapefruit) with mean values of 8.150 mg/100ml while lowest in T_4 (Musambi) with mean value of 7.420 mg/100ml (Table 2).

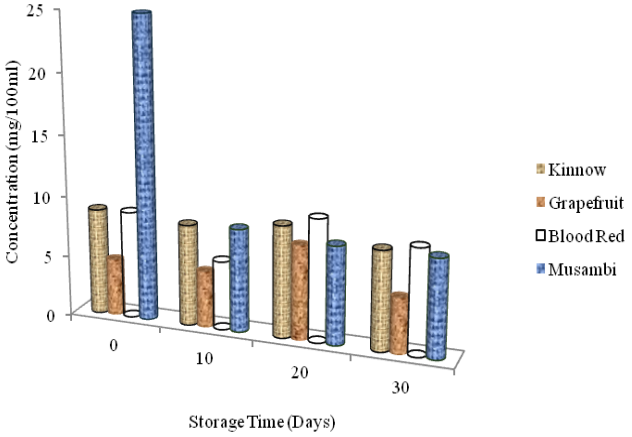

Fig. 1 Effect of storage on Sodium content in juices of different citrus cultivars

The interaction between storage time and treatment revealed higher sodium (4.850 mg/100ml) in T_4 at the initiation of experiment while the lowest T_2 at 30th day of storage with mean value 4.550 mg/100ml (Fig. 1). It was observed that sodium contents are not much affected by storage. No significant changes were observed in sodium contents during storage [28] (Kong et al., 1980). Sodium content of

juices in present investigation is higher as compared to earlier studies by Mbogo et al. [29] (2010) (2.54 mg/100 g-fw) observed in Navel oranges and 3.30 mg/100 g-fw in Valencia oranges. The results of this study are greater than previous findings. This variation may be due to higher mineral content in soil, environmental conditions or the results this study are in mg/100ml juice while in earlier studies results were presented as mg/100g on fruit basis.

Table 1. Analysis of variance for mineral contents in different citrus juices

Source	df	Na	K	Mg	Ca	Fe
Citrus sp	3	97.133**	527663.96**	12.487**	0.126**	1.925**
Storage	3	60.041**	47305.617**	0.234*	0.002*	3.860**
T×S	9	55.742**	140402.27**	0.055NS	5.882NS	0.777**
Error	32	0.181<	1303.688<	0.075	7.519	0.003<
Total	47					

3.2 POTASSIUM CONTENT: Potasum is very important element regarding the nerves system because it involves in the electron transport chain. In different citrus juices its quantity is maximum than any other mineral content. The statistical analysis showed highly significant affect of storage period, treatments and the first order interaction between storage time and treatment on the potassium content of citrus juices from different varieties (Table 1).

The highest potassium content was observed at the 30th day storage period with mean value 485.25 mg/100ml while lowest potassium (485.167 mg/100ml) was found at the 10th day of storage period (Fig. 2). Citrus species affected potassium of the citrus juices significantly and higher potassium contents were observed in T_3 (Kinnow) with mean values of 512.34 while lowest potassium value was observed in T_2 (Grapefruit) with mean value of 470.25 mg/100ml among all treatments (Table 2).

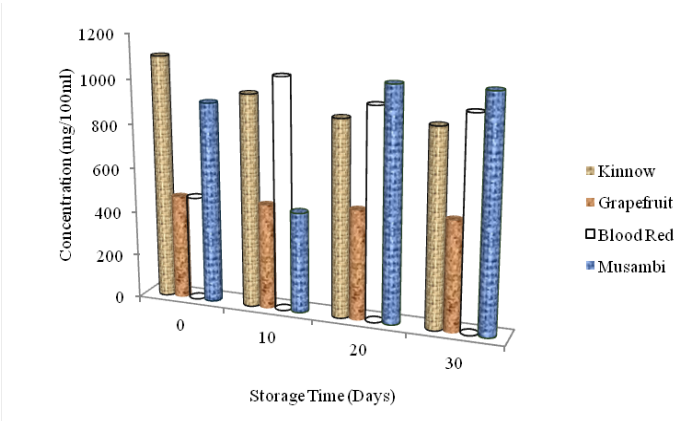

Fig. 2. Effect of storage on Potassium content in juices of different citrus cultivars

The interaction between storage time and treatment showed significantly higher potassium content (1100.343 mg/100ml) in T_1 at the start of storage while the lowest (453.780 mg/100ml) potassium was estimated in T_4 at 10th day (Fig. 2). It was observed that potassium contents are not much affected by storage.

Table 2. Concentration of different minerals in juices of citrus cultivars

Citrus Cultivars	Mineral Concentration (mg/100ml)				
	Na	K	Mg	Ca	Fe
Kinnow	8.035	472.620	7.484	0.734	0.326
Grapefruit	8.150	470.250	6.035	0.602	0.262
Blood Red	7.840	512.340	5.627	0.562	0.267
Musambi	7.420	485.550	5.427	0.542	0.251

Results of the current study are higher than previous findings by Dosumu et al. [11] (2009) who observed that K content of fruit beverages varied from 4.35 mg/ml to 5.85 mg/ml. Over all no significant change occur in potassium contents during storage which is in accordance with the statement of the [28] (Kong et al., 1980).

3.3 MAGNESIUM CONTENT: Magnesium is found in minute quantity in citrus juices; however, it is much important as health point of view. The statistical analysis given in showed that the magnesium of the citrus juices was highly significantly influenced by storage period and significantly by treatment (Table 1). The first order interaction between storage time and treatment showed non-significant influence on magnesium.

The highest magnesium content was observed at the end (30th day) of storage period with mean value 6.282 mg/100ml which is statistically at par with mean at 20th day while lowest magnesium was found at the 10th day of storage period with mean value of 5.426 mg/100ml which is similar to mean at 30th day (Fig. 3). Among treatments significantly higher magnesium was observed in T_1 with mean value (7.484 mg/100ml) while significantly the lowest in T_4 (mussambi) with mean value of 5.42 mg/100ml (Table 2).

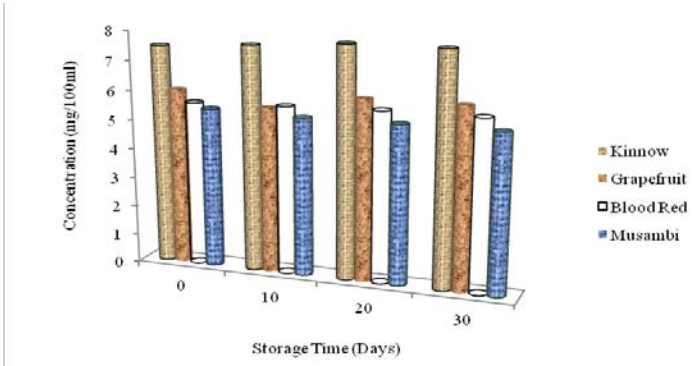

Fig. 3. Effect of storage on Magnesium content in juices of different citrus cultivars

Significantly higher magnesium was found in T_1 with mean value of 7.846 mg/100ml at the end of experiment while the lower magnesium was estimated at 10th day with mean value 5.426 mg/100ml which is statistically similar with mean value at 30th day in T_4. (Fig. 3). The magnesium ranged from minimum 5.426 mg/100ml to maximum 7.484 mg/100ml. It was observed that magnesium contents are not much affected by storage.

No significant change in magnesium contents occurred during storage [28] (Kong et al., 1980). The results of the current investigation are much lower than earlier investigations by Mbogo et al. (2010) who found that potassium content 172.10-mg/100 g-fw found in the Valencia oranges and the lowest value was 162.00 mg/100 g-fw found in Navel oranges. This variation may be due to lower mineral content in soil, environmental conditions or the expression of results (mg/100ml) juice in present study in comparison to previous findings presented as mg/100g on fruit basis. However, the results of current study are higher from previous findings (0.005-0.06 mg/ml) by Dosumu et al. [11] (2009) in different fruit drinks.

3.4 CALCIUM CONTENT: Calcium is important element regarding health point of view and essential for bone formation. Although citrus juice is not a good of calcium however it can be fortified in juices to overcome the deficiency of calcium. Calcium content of the citrus juices was highly significantly influenced by storage period while the effect of treatment was found to be significant (Table 1). The first order interaction between storage time and treatment also showed non-significant influence on calcium.

The highest calcium content was observed at the end of research work (0.750 mg/100ml) while insignificantly lowest calcium was found at the 10th day of storage period with mean value 0.542 mg/100ml (Fig. 4). The effect of treatments on calcium of the citrus juices showed significantly higher calcium content in T_1 with mean value of 0.773 mg/100ml while lowest value for calcium was observed in T_4 (mussambi) with mean value of 0.545 mg/100ml (Table 2).

The interaction between storage time and treatment showed the higher calcium with mean value of 0.785 mg/100ml in T_1 at the 20th of experiment while the lower calcium were estimated in T_4 at 20th day of the experiment with mean value 0.535 mg/100ml (Fig. 4). Storage period did not show any significant change in calcium contents of citrus juices.

Results of the present experiment are in line with earlier findings by Dosumu et al. [11] (2009) who noted that calcium content of fruit beverages vary between 0.560 to 0.925 mg/ml. The findings of present study agreed with the values as reported by [29] (Kenawi et al. 1994) who observed that the storage effect of ten weeks on calcium contents (4.5% and 4%) of calcium

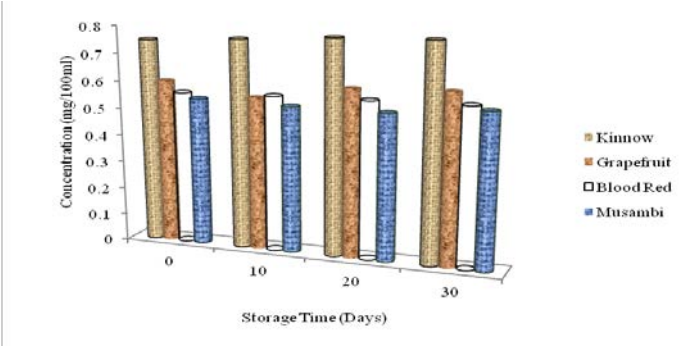

Fig. 4. Effect of storage on Calcium content in juices of different citrus cultivars

fortified orange juices concentrate in different packaging material is very slight or negligible during storage period of 111 days at 37°C. No significant change was observed in calcium contents during storage which is line with the statement of the [28] (Kong et al., 1980).

The results of the present study are lower than earlier investigations by Mbogo et al. [29] (2010) who noted that calcium content ranged from 30.25 mg/100g fw in Navel oranges to 33.00 mg/100g-fw in Valencia oranges. West et al. [30] (1988) observed range for calcium content 16.0 to 28.0 mg/100 g-fw for fruits in East Africa and 7.4 - 55.1 mg/100 g-fw reported by Aremu & Udoessien [31] (1990) for some Nigerian fruits. The amount of calcium present in the orange fruits was lower than the FAO value of 1.5 g/100 g. The results of this study are lower than previous findings. This variation may be due to lower mineral content in soil, environmental conditions or the results this study are in mg/100ml juice while in earlier studies results were presented as mg/100g on fruit basis.

3.5 IRON CONTENT: The health importance of iron cannot be denied because it is an important part of hemoglobin for carrying oxygen to the body tissues. Citrus juices are not a good of iron, however, it can be fortified in juices to overcome the deficiency of iron. Statistical analysis revealed that the effect of storage period, treatment and first order interaction between storage time and treatment was found to be highly significant influence on iron content of citrus juices (Table 1).

The highest iron content was observed at the end of storage period with mean value 0.287 mg/100ml while lowest iron was found at start of storage period 0.274 mg/100ml (Fig. 5). Highest value iron content was noted in T1 (0.3265 mg/100ml) while iron value was significantly lowest in T4 (red blood) 0.251 mg/100ml (Table 2).

The interaction between storage time and treatment showed that higher iron content (1.949 mg/100ml) was noted in T2 at the end of experiment while the lowest iron were estimated in T4 at the initiation of the experiment with mean value 0.188 mg/100ml (Fig. 5). It was observed that iron contents are not much affected by storage.

Results of current evaluation are in accordance with findings

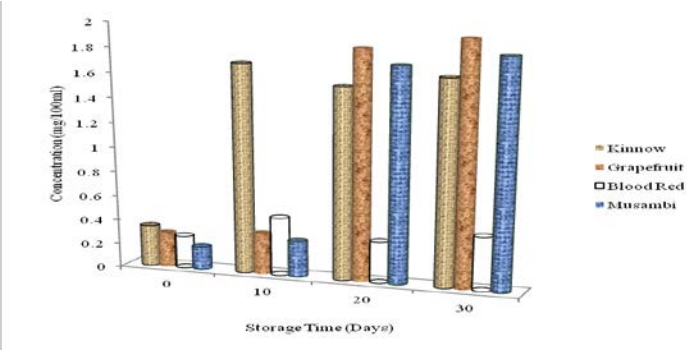

Fig. 5. Effect of storage on Iron content in juices of different citrus cultivars

of Dosumu et al. [11] (2009) who recorded iron content of different fruit beverages range from 0.005 to 0.025 mg/ml. The findings of current investigation agreed with the values as reported by [29] (Kenawi et al.,1992) that the storage effect of ten weeks on iron contents (4.5% and 4%) of iron fortified orange juices concentrate in different packaging material is very slight or negligible during storage period of 111 days at 37°C. Storage conditions showed no significant change in iron contents [28] (Kong et al., 1980).

4 CONCLUSIONS

The results of the present study indicate that citrus juices are beneficial for human health because these contain higher content of major minerals i.e. Sodium and Potassium. It is established fact that concentration of Potassium should be greater than that of Sodium in health promoting foods. Consumption of citrus juices is desirable as these are rich source of macro minerals. It is concluded from the results that citrus juices are excellent source of major inorganic elements in human body and safe for hypersensitive people because of lower amount of sodium in comparison to potassium. All minerals showed no particular trend during storage except iron which tend to increase subsequently during storage. Magnesium and calcium contents remain stable while sodium and potassium content showed a slight variation during storage.

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