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Post-Harvest Behavior of Different Lettuce Cultivars and their Cut Form sunder Different Storage Conditions

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***Abstract*—*The four leaf type lettuce cultivars i.e. GKL-1, GKL-2, GKL-3 and Chinese Yellow were evaluated for postharvest behavior during storage. The harvested fresh leaves of different lettuce cultivars were processed into two forms i.e. whole leaf form and cut form (5x3 cm) and were stored at two storage conditions i.e. refrigerated storage (5±1°C) and ZECC (9-15°C). Results revealed that whole leaf form of lettuce cultivars stored in refrigerated condition recorded minimum changes in physico-chemical parameters. With the advancement of storage period decrease in per cent moisture, ascorbic acid and polyphenol content was observed in all treatments irrespective of cultivars, forms and storage conditions. The maximum per cent browning and decay was observed in ZECC storage which was minimum in refrigerated storage.The whole leaf form of lettuce cultivar Chinese Yellow recorded shelf life of 15 days when stored at refrigerated storage (5±1^{0}C), whereas other cultivars (GKL-1, GKL-2 and GKL-3) recorded shelf life of 12 days. Whole leaf form of Lettuce cultivars stored in ZECC condition recorded shelf life upto 6 days while fresh-cut lettuce recorded shelf life of 3 days in ZECC. Fresh-cut lettuce recorded accelerated physiological loss in weight, moisture loss with increase in browning and decay percentage. Decrease in per cent moisture, ascorbic acid and polyphenol content with increase in physiological loss in weight was recorded in all treatments over the period of storage irrespective of cultivars, forms and storage conditions. The whole leaf form of lettuce cultivar Chinese Yellow recorded minimum changes in physico-chemical parameters and controlled enzymatic browning which maintained sensorial marketable quality and enhanced acceptability of lettuce leaves up to 15 days when stored at refrigerated storage (5±1°C).*

***Keywords*— Lettuce Cultivars, ZECC, GKL-1, GKL-2, GKL-3.**

I. INTRODUCTION

Lettuce (*Lactuca sativa*), is an important and fast emerging salad crop of Asteraceae family, originated in Asia and extensively grown in European countries, USA, Mexico, Chile, Argentina, Brazil, Peru, China, Japan and Australia. Among the three main type viz., leaf, head and cos or romaine (Bradley*et al*., 2009), leaf lettuce is commonly grown in India. Fresh-cut lettuce, which represents more than 80% of the total production of fresh-cut produce, has been one of the more highly requested commodities by fast food services and salad bars (Beltran, 2005). It became popular due to its crispy texture, attractive green leaves, neutral taste and green aroma (Rico*et al*., 2007) and widely known as the "queen of the salad plants" (Martin and Ruth 1975).Among the modern types of lettuce are two crisphead forms viz., iceberg which forms a large firm head and Batavia which is slightly softer and smaller than iceberg are popular in western countries. Romaine lettuce has long leaves in a loaf-shaped head. Butterhead lettuce is quite small with oily soft textured leaves. Red and green leaf lettuce form no head and have leaves with a variety of shapes. Less commonly found are the Latin type, which looks like a small romaine, and the aforementioned stem and oil seed lettuce. Iceberg lettuce is composed of soft leaves that contain large amounts of moisture (more than 95%), and is not only improves the appearance of the food, but also increases the nutritional value of mixed salads (Kang*et al*., 2007). It is predominantly used for prepared salads, but other types of lettuce are now being used in salad mixes. Information on the postharvest behavior of other lettuces is lacking, especially with regard to their quality in salad packs (Lopez-Galvez *et al*., 1996)

The demand for fresh-cut fruits and vegetables has been increasing over the past 10 years owing to the convenience of fresh-cut fruits and vegetables as ready-to-eat products coupled with the health benefits associated with their consumption (Rimm*et al*., 1996). Packaged salad-cut lettuce for food service and salad mixes is an increasingly important component of the lettuce industry (Glaser *et al*., 2001). However, it is well known that minimally processed fruits and vegetables are generally more perishable than the original raw materials (Rojas-Grau*et al*., 2008). The postharvest losses estimated in lettuce are in range of 20-30% (Serrato*et al*., 2014) due to mechanical stress during processing that results in cellular delocalization of enzymes and their substrates leading to biochemical deteriorations such as enzymatic browning, off-flavor and texture browning (Varoquaux, 1991).

Fresh-cut lettuce is highly perishable with a shelf life of 2-3 days due to high water content and running metabolic activities. Shelf life and the visual quality of salad-cut lettuce can be affected by the production environment, vegetative maturity, storage temperature, choice of cultivar and its cut forms used. (Chiesa*et al.*, 2003; Watada and Qi, 1999 and Couture *et al*., 1993) Cold storage and modified-atmosphere (MA) packaging are used to extend its shelf life. Postharvest losses in relation to quality and quantity of food are a major problem all over the world, which can be controlled by optimal storage time and temperature (Khan*et al.*, 2012; Lamikanra, 2002). Quality maintenance currently relies chiefly on the selection of suitable cultivars and the maintenance of low temperatures (optimum 1°C) during storage, distribution and retail (Ahvenainen, 2000). Postharvest storage time and temperature can have an influence on ascorbic acid content, antioxidant activity and total phenolic content (Lamikanra, 2002). The lettuce postharvest processing operation has several challenges due to large variations in respiration rate from different cultivars, large seasonal variation and postharvest storage duration prior to processing. Given the importance of the market, lettuce cultivars, breeding lines and populations should be selected for increased shelf life in cold storage environments. To implement this practice, effective evaluation method and knowledge of the genetic variation within lettuce for shelf life is needed. Therefore, the present research work is proposed to determine and study the postharvest behavior of different lettuce cultivars and their cut forms at different storage temperatures.

II. MATERIALS AND METHODS

The present investigation on evaluation of lettuce cultivars and their forms for postharvest behavior during storage was conducted in the Post-harvest Technology laboratory of Horticulture Section, College of Agriculture, Kolhapur from July to August, 2015.The lettuce crop selected for investigation was of leaf type. The healthy, fresh photosynthetically active lettuce leaves of optimal maturity of four cultivars viz., GKL-1, GKL-2, GKL-3 and Chinese Yellow were collected from Instructional-cum-research farm of Horticulture section, College of Agriculture, Kolhapur. They were prepared for storage on the same day. The lettuce leaves of different cultivars were sorted for integrity, color and size uniformity, and lack of defects. Outer leaves were discarded to reduce natural variability among samples and only photosynthetic leaves (green leaves) were included in the samples. Lettuce leaves were washed in running tap water for 4 min at room temperature (20°C) in a ratio of one part of lettuce for 10 parts of water. Excess water was drained by using sterilized stainless steel sieve. Intact leaves were used for whole lettuce form while the cut form of fresh-cut lettuce was prepared by cutting leaves into 5x3 cm size and by shredding into 1x0.5 cm with sharpened stainless steel knife sterilized in alcohol at 13°C temperature. Food grade sodium hypochlorite solution 150 mg L^{-1} was used for dipping of lettuce for 15 min. Processed lettuce leaves weighing 250 g were filled in consumer polypropylene food grade plastic bags of 25x20 cm size and 150 gauge thick with low permeability for moisture. A closed glass chamber was prepared. The gas cylinder was fixed to inlets. The internal gas flow was regulated and weighed lettuce was filled in bags and were flushed with 100% nitrogen gas. Storage studies were conducted at different conditions viz; refrigerated storage at 5±1°C, ZECC at 9-15°C and ambient storage at 25-30°C. Pilot trials were conducted from January to February 2015 for different lettuce cultivars by applying the storage environment and cut forms revealed that shelf life of all forms of lettuce at ambient storage and of shredded lettuce at all temperatures was upto 2-3 days only. Hence in final trial, conducted from July to August 2015, ambient storage treatment and shredded form of lettuce treatment were deleted. Samples were evaluated every 3 days interval.

Physico-chemical analysis

The percent moisture was determined by drying known weight of sample into hot air oven (Metalab) at 60°C for 24 hours for a constant known weight. (A.O.A.C. 2010).Weight loss was estimated based on the fresh produce weight and the significant change in physiological weight loss of lettuce leaves during storage was determined on percentage basis. In all samplings the fresh weight was measured by an electronic scale of ±0.01 g accuracy and reduction in weight over initial weight in percentage was calculated according to Akhter*et al*. (2013). Ascorbic acid was estimated as per the modified visual titration procedure of A.O.A.C (2010) and calculated in terms of mg per 100g of fresh-cut leaves.The Phenol content in lettuce leaves was determined by colorimetric method using Folin-Denis reagent (A.O.A.C., 2005). The optical density was read at 760 nm on spectronic-20 and phenols were expressed as mg of gallic acid equivalents per 100g FW of sample.The lettuce surface browning was determined visually on weight basis of lettuce and expressed in percentage as stated by Khumjing*et al.* (2011).The percent decay of lettuce leaves during storage was calculated based on visual inspection of each leaf for infection. Percent decay was calculated according to Gihan (2010) on weight basis.

III. RESULT AND DISCUSSION

As regards ZECC storage conditions, considering the condition of lettuce samples, the data was recorded up to 6 days only while in case of fresh-cut form of lettuce, the data was recorded only for 9 days. Thereafter both the treatments were terminated. All the lettuce cultivars except Chinese Yellow, had the marketable acceptability up to 12 days only. In respect of the lettuce cultivar Chinese Yellow observations were recorded upto 15 days.

Percent moisture and physiological loss in weight (%)

Weight loss is a very important factor as it is associated with economic issues and generally weight loss more than 5% reduces the market value of vegetables (Brown and Bourne, 2002). Water loss in vegetables is determined by many factors, the most important of which is the resistance exerted by the outer periderm or cuticle movement of water vapour due to transpiration as reported by Ben-Yehoshua(1987). However cutting of produce results in resistance reduction of these barriers to transpiration. Cut products are highly susceptible to physiological weight loss because internal tissues are exposed to atmospheric conditions than the intact products. In present study, the per cent moisture of lettuce leaves was significantly influenced by different cultivars, cut forms, storage conditions and their interactions. Maximum per cent moisture (90.15% on 15th day) and minimum physiological loss in weight (0.99% on 15th day) was recorded in treatment $V_4T_1F_1$ (whole leaf form of lettuce cultivar Chinese yellow stored in refrigerated storage). The low storage conditions (5±1°C) and high relative humidity conditions maintained throughout the storage period along with the lowest cutting grade i.e. whole leaf could be the possible reasons of maintenance of per cent moisture upto 15 days. However, slight moisture losses were recorded during the storage this might be due to respiratory activities, induction of new enzymes and membrane degradation of lettuce leaves as reported by Mattos*et al.* (2013) in fresh-cut lettuce; Moretti *et al.* (2007) in baby carrots.

The physiological loss in weight increased with decrease in moisture content of fresh lettuce leaves. The loss in per cent moisture resulted in reduction of fresh weight accompanied by the loss of freshness, appearance and texture as observed by Manolopoulou and Varzakas (2011). Evaporation, transpiration and respiration of fresh-cut leaves after harvest and imbalance of vapor pressure in the product tissues and the air inside the package lead towards weight loss over time as reported by Moreira *et al*. (2006). In addition to modified atmosphere packaging (N_2 flushing), use of polypropylene bag and low temperature storage condition were the most important factors in preventing water loss. Similar findings were reported by Ansah*et al*. (2015) in fresh-cut iceberg lettuce, Serea*etal.* (2014) in fresh lettuce leaves and by Manolopoulou et al. (2010) in fresh-cut Romaine lettuce. For the samples stored under refrigerated conditions @ 5±1°C,dehydration was not a major problem but it affected the samples stored in ZECC (Table 1 and Fig. 2). Only slight changes in physiological loss in weight were found during the entire period of storage for all treatments as observed by Kang *et al*. (2007) in fresh-cut lettuce. The weight loss increased with the increase in temperature ofstorage conditions throughout the storage period, the findings of present study were in favour of Moreira *et al*. (2006) in lettuce leaves and Kim *et al*. (2004) in salad savoy. The temperature and relative humidity must be controlled forpreventing the moisture loss of vegetables as reported by Thompson (2004).The fresh-cut iceberg lettuce was highly susceptible to dehydration as observed by Kang*et al*. (2007). Minimum cutting of tissue and low temperature storage maintained the weight for maximum period, the similar results were also reported byRazali*et al*. (2004) in minimally

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processed long beans and by Tuncayand Kusaksiz (2003) in cut leeks.

Browning percentage

Polyphenol oxidase is an enzyme implicated in the enzymatic browning process. Increase in polyphenol activity during storage contribute to browning which was measured on per cent basis of fresh weight of lettuce in this study as reported by Martin-Diana *et al.* (2005) in salad-cut iceberg lettuce and by Loaiza-Velarde *et al*. (2001) in fresh-cut celery petiole. Browning is the main cause of quality loss in minimally processed lettuce. Oxygen (O_2)is necessary substrate in the enzymatic browning as observed by Sandhya (2010) on fresh produce and by Jacxsense*t al.* (2001) in fresh-cut lettuce. Slow increase in browning per cent (Table 2 and Fig. 2) in lettuce leaves might be due to inhibition of necessary substrate required for browning i.e nitrogen flushing as reported by Mattos*et al*. 2013 in fresh-cut crisphead lettuce.

Lettuce cultivar Chinese Yellow recorded minimum per cent browning (4.17% on 15th day) as compared to other cultivars. Differences in browning potential among the lettuce cultivars was observed, it might be due to variations in phenolic metabolism as reported by Hyodo*et al*. (1978) in various lettuce cultivars. The maximum percentage of browning (3.93% on 9th day) was observed in cut form of lettuce this might be due to cutting of leaves which increase polyphenol oxidase activity due to provoking of tissue wounding which in turn has might increased respiration rate and ethylene emission as well as increase in phenylalanine ammonia lyase activity and soluble phenolic content stimulating browning, the results are in conformity with Castaner*et al*. (1999) in baby and romaine lettuce, Mattila*et al*. (1995) in minimally processed vegetables,Mateos*et al*. (1993) in lettuce and Ke and Saltveit(1989) in iceberg lettuce. In photosynthetic tissue, soluble brown pigments slowly increased during storage, showing the similar trend in all lettuce cultivars. This suggests that the photosynthetic tissue also developed browning although other natural pigmentssuch as chlorophyll masked the brown discoloration. In all the treatments browning percentage increased with increase in temperature during storage and was minimum at low temperature storage (Refrigerated storage @ 5±1°C). This might be due to lowering down the metabolic activities due to low temperature. These results are in conformity with the results reported by Grzegorzewska (2007) in fresh-cut crisp lettuce and Castaner*et al*. (1999) in baby and romaine lettuce.

Decay percent

Increasing trend for per cent decay was observed throughout the storage period as summarized in Table 2 and Fig. 2. Among the cut forms, whole leaf formof lettuce reported minimum decay (1.89% on 9th day) than cut form (2.73% on 9th day) of lettuce as observed by Mattila*et al*. (1995). The decay percentage increased was found to be increased with the increase in storage temperature as reported by Grzegorzewska (2007) and by Kim *et al*. (2004). Increase in per cent decay in cut form might be due to the increase in wounded tissue surface that cause condensation in the lettuce bags which created aqueous focuses for the development of microorganisms which leads to decay. The low levels of oxygen favours fermentation processes which might cause the formation of theacetaldehyde and off flavour compounds which may cause decay as reported by Kays and Kapoor, 2000 in minimally processed fruits and vegetables. Maximumper cent decay (2.46% on 6th day) was observed for samples stored in ZECC due to higher temperature storage condition and higher humidity. The 100% nitrogen flushing in lettuce packages and low temperature storage (5±1^{0}C) was helpful in preventing the decay percentage (1.50% on 6thday) as reported by Serea*et al.*, (2014) and Luo*et al.*, (2010) in minimally processed iceberg and Romaine lettuce.

Ascorbic acid (mg/100g)

Ascorbic acid is a cofactor in numerous enzymatic reactions and an important nutritional component of fruit and vegetables. It is very labile and its preservation is of crucial importance to the human diet (Ezell and Wilcox, 1959). Ascorbic acid is the predominant form of vitamin-C in fresh-cut iceberg lettuce, representing 55-65% of the total vitamin C content. The initial ascorbic acid content of lettuce leaves ranged between 11.61 to 11.82 mg/100g. The results are in conformity with Moreira*et al*. (2006).

Maximum ascorbic acid (11.24 mg/100g on 15th day) was observed in whole leaf form of Chinese Yellow cultivar stored in refrigerated storage throughout the storage period. However, with advancement of storage period decrease in ascorbic acid content was observed (Table 3 and Fig. 3) in all treatments. These results are in conformity with Spinardi*et al*. (2010) in baby lettuce. Maximum loss of ascorbic acid was observed in cut form of lettuce cultivars stored in ZECC conditions (11.25 mg/100g on 6th day) this might be due to the affinity of ascorbic acid towards water, its thermal destruction, increase surface area and wounding and enzymatic oxidation during storage as reported by Selmon (1994). Also increase in storage time and respiration might has played important role in ascorbic acid reduction as reported by Sharma*et al*. (2011) in minimally processed vegetables, Spinardi*et al*. (2010) in spinach and lettuce baby leaf, Ferrante *et al*. (2009) in lambs lettuce, Myojin*et al*. (2008) in bellpepper andLamikarana*et al*. (2002) in fresh-cut fruits and vegetables. The stability of ascorbic acid is generally enforced by maintaining low temperature duringstorage (Fennema, 1996). Loss in ascorbic acid is attributed to both, temperature and water loss (Kader, 2002). The rate of degradation of ascorbic acid in lettuce leaves stored at abusive temperature storage conditions (ZECC and ambient storage) (11.25 mg/100g on 6th day) was faster than at low temperature storage condition (0°C) (11.41 mg/100g on 6th day) as observed by Moreira*et al*. (2006).

The whole leaf form of lettuce recorded maximum ascorbic acid content (11.24 mg/100g on 15th day) at the end of storage these might be due to the photosynthetic activity and absence of wound which might have decreased respiration rate and ethylene formation. Cutting of vegetables leads to decrease in ascorbic acid at higher rate than whole intact leaves which might be due to increase in ethylene production due to cut made in fresh-cut products and this ethylene could stimulate other physiological processes such as the degradation of vitamin C etc. as reported by Cocetta*et al*. (2014) in fresh-cut baby spinach and by Kader (1985) in vegetables. Gradual decrease in ascorbic acid content observed in this experiment could be connected with increase in breathing intensity after minimal processing. The organic acids together with another compounds take part in the breathing reactions, as a result the total content of acids decreases and pH value increase as reported by Soliva-Fortuny *et al.* (2003) and Luo *et al*. (2010) in lettuce.

Polyphenol (mg/100g)

Initial polyphenolic content (mg/100g) of lettuce leaves ranged from 8.6 to 8.7 mg/100g (Table 3 and Fig. 3). Scarce changes were observed in polyphenol content over the storage period. Polyphenol content showed a decreasing trend with time. This could be due to the reduced plant biochemical processes, such as production of ethylene, respiration, enzymatic activities as a result of low oxygen environment and low storage temperature. However, the slight reduction in polyphenols might be due to the use of polyphenols as substrate for the polyphenol enzyme and the conversion between free and bound phenolic substances as reported by Ferrante*et al.* (2009) in lambs lettuce.

The main interest of polyphenol analysis was to evaluate the possible effect of cultivars, cut forms and storage conditions of lettuce leaves on the polyphenolic content which is responsible for antioxidant activity. The phenolic compounds accumulate in lettuce leaves, and are associated with subsequent tissue browning. Polyphenols decreased much more slowly in refrigerated storage (8.65 mg/100g on 6th day) than ZECC (9-15°C) (8.62 mg/100 on 6th day). This might be due to low temperature which slowed down plant metabolic processes, such as respiration, ethylene production and enzyme activity. The decrease in polyphenols was maximum in fresh-cut lettuce (8.61 mg/100g on 9th day) than whole leaf form (8.64 mg/100g on 9th day). The polyphenol oxidase and polyphenols are found in different organelles of plant cells. When tissue is damaged, they meet and react with each other. As a result the polyphenols decrease at a rapid rate in cut tissues than intact leaves. The results of present study are in close conformity with the results obtained by Altunkaya andGokmen (2007) in lettuce.

IV. SUMMARY AND CONCLUSIONS

The data on initial analysis of cultivars revealed that Chinese Yellow cultivar had highest level of ascorbic acid (11.82 mg/100g), phenols (8.72 mg/100g) and moisture (92.67%) followed by GKL-3 and GKL-2 and lowest content of all parameters was recorded in GKL-1. Whole leaf form of Chinese Yellow cultivar recorded shelf life of 15 days at refrigerated storage and 6 days at ZECC while whole leaf form of GKL-1, GKL-2 and GKL-3 recorded shelf life of 12 days at refrigerated storage condition. Cut leaf form of lettuce cultivars recorded shelf-life of 9 days at refrigerated storage and 3 days at ZECC. The minimum changes in physico-chemical parameters of lettuce cultivars were recorded under refrigerated storage as compared to ZECC storage. Decrease in per cent moisture, ascorbic acid and polyphenol content was observed in treatments irrespective of cultivars, forms and storage conditions. The maximum per cent browning and decay was observed in cut form of lettuce stored in ZECC storage. The lettuce cultivar Chinese Yellow recorded minimum changes in physico-chemical parameters throughout the storage period. In respect of interaction effect cut form of lettuce cultivar GKL-1 stored in ZECC ($V_1T_2F_2$)registered maximum changes in regards of physico-chemical parameters while maximum retention was recorded by whole leaf form of Chinese Yellow cultivar stored in refrigerated storage ($V_4T_1F_1$).

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Table.1: Effect of different lettuce cultivars, cut forms and storage conditions on the changes in percent moisture and physiological loss in weight (%)

Treatment combinations	Percent moisture			Physiological loss in weight		
	Storage period (days)					
	9	12	15	9	12	15
V1	89.92^{a}	89.81^{a}	-	0.87^{d}	0.97^{c}	-
V2	90.12^{b}	90.02^{b}	-	0.86^{c}	0.95^{bc}	-
V3	90.65^{c}	90.49^{c}	-	0.84^{b}	0.93^{b}	-
V4	90.94^{d}	90.69^{d}	90.15	0.78^{a}	0.82^{a}	0.99
SE	0.002	0.001		0.0006	0.0006	
CD at 1%	0.008	0.003		0.0024	0.0023	
T1	90.41	90.25	90.15	0.84	0.91	0.99
T2	-	-	-	-	-	-
SE						
CD at 1%						
F1	90.89	90.25	90.15	0.72	0.91	0.99
F2	89.92	-	-	0.96	-	-
SE	0.002			0.0005		
CD at 1%	0.007			0.0021		
V1T1	89.92	89.81	-	0.87	0.97	-
V1T2	-	-	-	-	-	-
V2T1	90.12	90.02	-	0.86	0.95	-
V2T2	-	-	-	-	-	-

V3T1	90.65	90.49	-	0.84	0.93	-
V3T2	-	-	-	-	-	-
V4T1	90.94	90.69	90.15	0.78	0.82	0.99
V4T2	-	-	-	-	-	-
SE	0.004	0.001		0.0011	0.0011	
CD at 1%	0.014	0.005		0.0041	0.0040	
V1F1	90.58	89.81	-	0.75	0.97	-
V1F2	89.25	-	-	0.99	-	-
V2F1	90.78	90.02	-	0.74	0.95	-
V2F2	89.46	-	-	0.98	-	-
V3F1	90.91	90.49	-	0.73	0.93	-
V3F2	90.39	-	-	0.96	-	-
V4F1	91.29	90.69	90.15	0.66	0.82	0.99
V4F2	90.59	-	-	0.90	-	-
SE	0.004	0.001		0.0011	0.0011	
CD at 1%	0.014	0.005		0.0041	0.0040	
T1F1	90.89	90.25	90.15	0.72	0.91	0.99
T1F2	89.92	-	-	0.96	-	-
T2F1	-	-	-	-	-	-
T2F2	-	-	-	-	-	-
SE	0.003			0.0009		
CD at 1%	0.012			0.0036		
V1T1F1	90.58	89.81	-	0.75	0.97	-
V1T1F2	89.25	-	-	0.99	-	-
V1T2F1	-	-	-	-	-	-
V1T2F2	-	-	-	-	-	-
V2T1F1	90.78	90.02	-	0.74	0.95	-
V2T1F2	89.46	-	-	0.98	-	-
V2T2F1	-	-	-	-	-	-
V2T2F2	-	-	-	-	-	-
V3T1F1	90.91	90.49	-	0.73	0.93	-
V3T1F2	90.39	-	-	0.96	-	-
V3T2F1	-	-	-	-	-	-
V3T2F2	-	-	--	-	-	-
V4T1F1	91.29	90.69	90.15	0.66	0.82	0.99
V4T1F2	90.59	-	-	0.90	-	-
V4T2F1	-	-	-	-	-	-
V4T2F2	-	-	-	-	-	-
SE	0.006	0.002		0.0019	0.0018	
CD at 1%	0.024	0.008		0.0072	0.0070	

`-‘ indicates termination of treatments *Duncan’s Multiple Range Test *(P≤0.05)*

V_1= GKL-1 T_1= Refrigerated storage (5±1°C)

V_2= GKL-2 T_2= ZECC (9-15°C)

V_3= GKL-3 F_1= Whole leaf

V_4= Chinese yellow F_2= Cut form

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Table.2: Effect of different lettuce cultivars, cut forms and storage conditions on the changes in browning and decay percentage

Treatment combinations	Browning percentage			Decay percentage		
	Storage period (days)					
	9	12	15	9	12	15
V1	4.03 (0.07)^{d}	4.38 (0.08)^{d}	-	2.61 (0.05)^{d}	3.03 (0.05)^{d}	-
V2	3.69 (0.06)^{c}	4.02 (0.07)^{c}	-	2.43 (0.04)^{c}	2.84 (0.05)^{c}	-
V3	3.51 (0.06)^{b}	3.92 (0.07)^{b}	-	2.20 (0.04)^{b}	2.55 (0.04)^{b}	-
V4	3.17 (0.06)^{a}	3.79 (0.07)^{a}	4.17 (0.07)	2.01 (0.04)^{a}	2.21 (0.04)^{a}	2.87 (0.05)
SE	0.00008	0.00004		0.00004	0.00003	
CD at 1%	0.00029	0.00014		0.00011	0.00009	
T1	3.60 (0.06)	4.03 (0.07)	4.17 (0.07)	2.31 (0.04)	2.65 (0.05)	2.87 (0.05)
T2	-	-	-	-	-	-
SE						
CD at 1%						
F1	3.27 (0.06)	4.03 (0.07)	4.17 (0.07)	1.89 (0.03)	2.65 (0.05)	2.87 (0.05)
F2	3.93 (0.07)	-	-	2.73 (0.048)	-	-
SE	0.00007			0.00003		0.00011
CD at 1%	0.00025			0.00009		0.00044
V1T1	4.03 (0.07)	4.38 (0.08)	-	2.61 (0.05)	3.03 (0.05)	-
V1T2	-	-	-	-	-	-
V2T1	3.69 (0.06)	4.02 (0.07)	-	2.43 (0.04)	2.84 (0.05)	-
V2T2	-	-	-	-	-	-
V3T1	3.51 (0.06)	3.92 (0.07)	-	2.20 (0.04)	2.55 (0.04)	-
V3T2	-	-	-	-	-	
V4T1	3.17 (0.06)	3.79 (0.07)	4.17 (0.07)	2.01 (0.04)	2.21 (0.04)	2.87 (0.05)
V4T2	-	-	-	-	-	-
SE	0.00013	0.00007		0.00006	0.00005	
CD at 1%	0.00051	0.00025		0.00018	0.00015	
V1F1	3.72 (0.06)	4.38 (0.08)	-	2.15 (0.04)	3.03 (0.05)	-
V1F2	4.34 (0.08)	-	-	3.07 (0.05)	-	-
V2F1	3.38 (0.06)	4.02 (0.07)	-	1.93 (0.03)	2.84 (0.05)	-
V2F2	4.01 (0.07)	-	-	2.94 (0.05)	-	-
V3F1	3.20 (0.06)	3.92 (0.07)	-	1.85 (0.03)	2.55 (0.04)	-
V3F2	3.82 (0.07)	-	-	2.56 (0.04)	-	-
V4F1	2.77 (0.05)	3.79 (0.07)	4.17 (0.07)	1.65 (0.03)	2.21 (0.04)	2.87 (0.05)
V4F2	3.57 (0.06)	-	-	2.38 (0.04)	-	-
SE	0.00013	0.00007		0.00006	0.00005	
CD at 1%	0.00051	0.00025		0.00018	0.00015	
T1F1	3.27 (0.06)	4.03 (0.07)	4.17 (0.07)	1.89 (0.03)	2.65 (0.05)	2.87 (0.05)
T1F2	3.93 (0.07)	-	-	2.73 (0.050	-	-
T2F1	-	-	-	-	-	-
T2F2	-	-	-	-	-	-
SE	0.00011			0.00006		
CD at 1%	0.00044			0.00016		
V1T1F1	3.72 (0.06)	4.38 (0.08)	-	2.15 (0.04)	3.03 (0.05)	-
V1T1F2	4.34 (0.08)	-	-	3.07 (0.05)	-	-

V1T2F1	-	-	-	-	-	-
V1T2F2	-	-	-	-	-	-
V2T1F1	3.37 (0.06)	4.02 (0.07)	-	1.93 (0.03)	2.84 (0.050	-
V2T1F2	4.01 (0.07)	-	-	2.94 (0.05)	-	-
V2T2F1	-	-	-	-	-	-
V2T2F2	-	-	-	-	-	-
V3T1F1	3.2 (0.06)	3.92 (0.07)	-	1.85 (0.030	2.55 (0.04)	-
V3T1F2	3.82 (0.07)	-	-	2.56 (0.04)	-	-
V3T2F1	-	-	-	-	-	-
V3T2F2	-	-	-	-	-	-
V4T1F1	2.76 (0.05)	3.79 (0.07)	4.16 (0.07)	1.65 (0.03)	2.21 (0.04)	2.87 (0.05)
V4T1F2	3.56 (0.06)	-	-	2.38 (0.04)	-	-
V4T2F1	-	-	-	-	-	-
V4T2F2	-	-	-	-	-	-
SE	0.00023	0.00011		0.00011	0.00009	
CD at 1%	0.00088	0.00043		0.00032	0.00026	

`-‘ indicates termination of treatments *Duncan’s Multiple Range Test *($P\leq0.05$)*

*Figures in parenthesis indicate the corresponding arcsine value

V_1= GKL-1 T_1= Refrigerated storage (5±1°C)

V_2= GKL-2 T_2= ZECC (9-15°C)

V_3= GKL-3 F_1= Whole leaf

V_4= Chinese yellow F_2= Cut form

Table.3: Effect of different lettuce cultivars, cut forms and storage conditions on the changes in ascorbic acid content and polyphenols content (mg/100g GAE)

Treatment combinations	**Ascorbic acid content**			**Polyphenols content**		
	Storage period (days)					
	9	**12**	**15**	**9**	**12**	**15**
V1	11.20^{a}	11.16^{a}	-	8.59^{a}	8.58^{a}	-
V2	11.29^{b}	11.24^{b}	-	8.61^{b}	8.60^{b}	-
V3	11.34^{c}	11.30^{c}	-	8.65^{c}	8.63^{c}	-
V4	11.41^{d}	11.38^{d}	11.24	8.65^{d}	8.64^{d}	8.61
SE	0.001	0.001		0.0002	0.0001	
CD at 1%	0.004	0.003		0.0009	0.0003	
T1	11.31	11.27	11.24	8.63	8.62	8.61
T2	-	-	-	-	-	-
SE						
CD at 1%						
F1	11.34	11.27	11.24	8.64	8.62	8.61
F2	11.28	-	-	8.61	-	-
SE	0.001			0.0002		
CD at 1%	0.003			0.0008		
V1T1	11.20	11.16	-	8.59	8.58	-
V1T2	-	-	-	-	-	-
V2T1	11.29	11.24	-	8.61	8.60	-
V2T2	-	-	-	-	-	-

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V3T1	11.34	11.30	-	8.65	8.63	-
V3T2	-	-	-	-	-	-
V4T1	11.41	11.38	11.24	8.65	8.64	8.61
V4T2	-	-	-	-	-	-
SE	0.002	0.001		0.0004	0.0001	
CD at 1%	0.007	0.006		0.0016	0.0006	
V1F1	11.23	11.16	-	8.60	8.58	-
V1F2	11.17	-	-	8.58	-	-
V2F1	11.33	11.24	-	8.63	8.60	-
V2F2	11.26	-	-	8.60	-	-
V3F1	11.37	11.30	-	8.66	8.63	-
V3F2	11.31	-	-	8.64	-	-
V4F1	11.44	11.38	11.24	8.66	8.64	8.61
V4F2	11.38	-	-	8.64	-	-
SE	0.002	0.001		0.0004	0.0001	
CD at 1%	0.007	0.006		0.0016	0.0006	
T1F1	11.34	11.27	11.24	8.64	8.62	8.61
T1F2	11.28	-	-	8.61	-	-
T2F1	-	-	-	-	-	-
T2F2	-	-	-	-	-	-
SE	0.002			0.0004		
CD at 1%	0.006			0.0014		
V1T1F1	11.23	11.16	-	8.60	8.58	-
V1T1F2	11.17	-	-	8.58	-	-
V1T2F1	-	-	-	-	-	-
V1T2F2	-	-	-	-	-	-
V2T1F1	11.33	11.24	-	8.63	8.60	-
V2T1F2	11.26	-	-	8.60	-	-
V2T2F1	-	-	-	-	-	-
V2T2F2	-	-	-	-	-	-
V3T1F1	11.37	11.30	-	8.66	8.63	-
V3T1F2	11.31	-	-	8.64	-	-
V3T2F1	-	-	-	-	-	-
V3T2F2	-	-	-	-	-	-
V4T1F1	11.44	11.38	11.24	8.66	8.64	8.61
V4T1F2	11.38	-	-	8.64	-	-
V4T2F1	-	-	-	-	-	-
V4T2F2	-	-	-	-	-	-
SE	0.003	0.003		0.0007	0.0003	
CD at 1%	0.012	0.010		0.0028	0.0010	

`-‘ indicates termination of treatments *Duncan’s Multiple Range Test *(P≤0.05)*

V_1= GKL-1 T_1= Refrigerated storage (5±1°C)

V_2= GKL-2 T_2= ZECC (9-15°C)

V_3= GKL-3 F_1= Whole leaf

V_4= Chinese yellow F_2= Cut form

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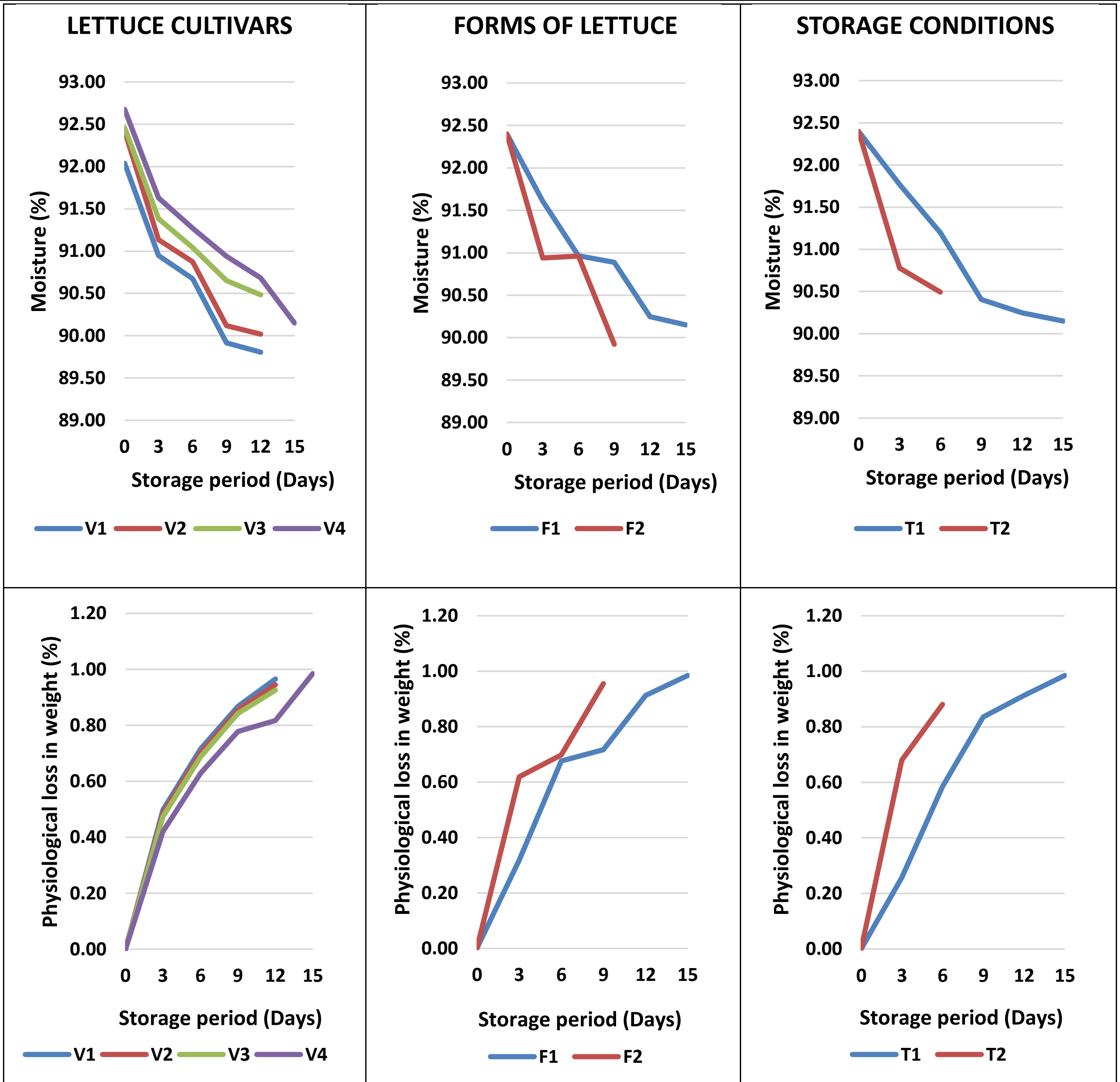

V1= GKL-1
V2= GKL-2
V3= GKL-3
V4= Chinese yellow

F1= Whole leaf
F2= Cut form

T1= Refrigerated storage (5±1°C)
T2= ZECC (9-15°C)

Fig.1: Effect of different lettuce cultivars, cut forms and storage conditions on percent moisture and physiological loss in weight

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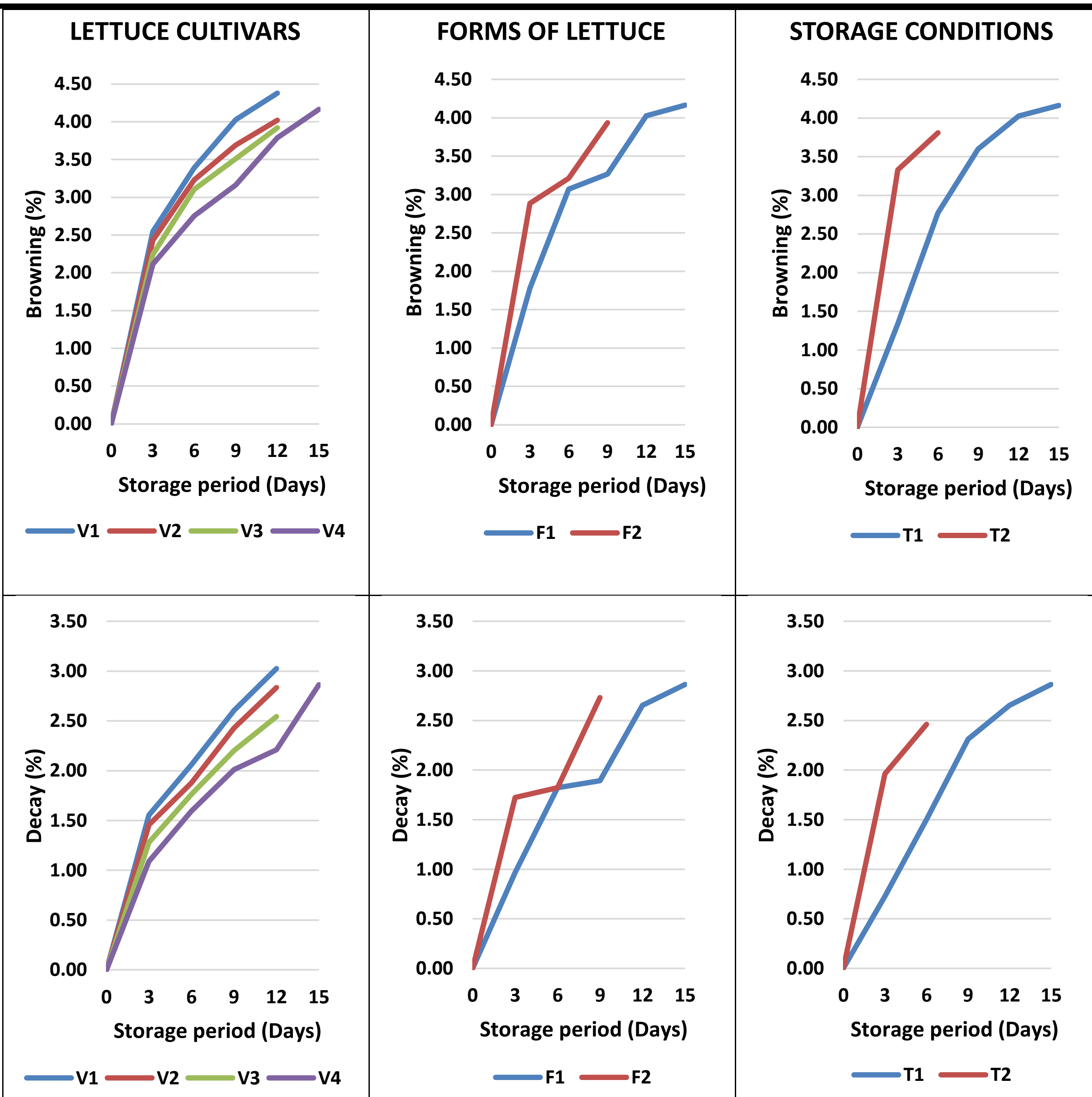

V_1= GKL-1
V_2= GKL-2
V_3= GKL-3
V_4= Chinese yellow

F_1= Whole leaf
F_2= Cut form

T_1= Refrigerated storage (5±1°C)
T_2= ZECC (9-15°C)

Fig.2: Effect of different lettuce cultivars, cut forms and storage conditions on browning and decay percentage

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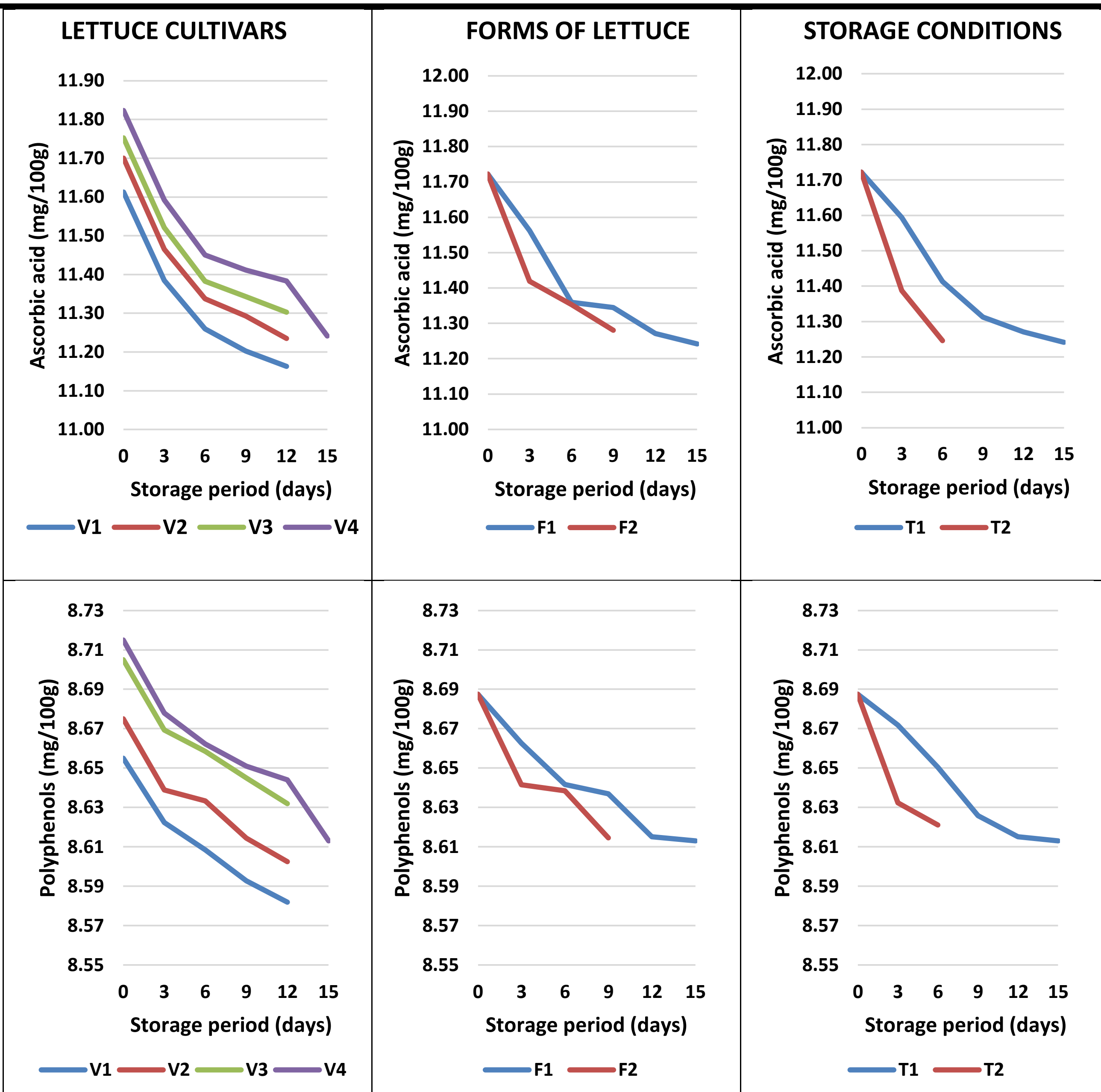

V_1= GKL-1
V_2= GKL-2
V_3= GKL-3
V_4= Chinese yellow

F_1= Whole leaf
F_2= Cut form

T_1= Refrigerated storage (5±1°C)
T_2= ZECC (9-15°C)

Fig.3: Effect of different lettuce cultivars, cut forms and storage conditions on ascorbic acid and polyphenols content