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Storage Stability of Potato Variety Lady Rosetta under Comparative Temperature Regimes

(Kestabilan Penyimpanan Varieti Kentang *Lady Rosetta* di bawah Perbandingan Regim Suhu)

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ABSTRACT

Potatoes are usually stored under low temperatures for sprout prevention and to ensure their continuous supply. Low temperature sweetening in potato is the major temperature related disorder being faced by the growers and is also known to be associated with variety specific storage temperature. The present study aimed at identifying the appropriate storage temperature for the premium potato variety *Lady Rosetta* with special reference to the changes in its quality attributes, that is weight loss, total sugars, starch, ascorbic acids, total phenolic contents, radical scavenging activity, enzymatic activities and potato chip color. The selected potato variety was stored under different temperature (5, 15 and 25°C) regimes to identify appropriate storage temperature. Our results showed significant variations in the tested quality attributes in response to different storage temperatures. Storage at 5°C maintained tuber dormancy up to 126 days, however, found associated with increased sugar accumulation (2.32 g/100 g), rapid starch depletion (13.25 g/100 g) and poor post processing performance (L-value, 52.00). In contrast, potato storage at 15°C retained lower sugar contents (1.33 g/100g) and superior chip color (L-value, 59.33) till the end of storage. However, they were found associated with the increased polyphenol oxidase (38.47 U/g f.w) and peroxidase (15.25 U/100 g f.w) activities as compare to those potatoes stored at 5°C during the same storage period. Storage life of potato tubers at 25°C was significantly reduced due to dormancy break on 84th day and subsequent starch degradation (15.29 g/100 g) increased sugar accumulation (1.32 g/100 g) and increased polyphenol oxidase (79.89 U/g f.w) and peroxidase activities (40.69 U/100 g f.w). Our results showed that potato variety *Lady Rosetta* is cold sensitive and requires specific temperature for prolonged storage and best post processing performance.

Keywords: Chip quality; enzyme activity; potato; physico-chemical attributes; temperature storage

ABSTRAK

Kentang biasanya disimpan pada suhu yang rendah untuk mencegah percambahan dan bagi memastikan bekalan yang berterusan. Pemanisan kentang pada suhu rendah adalah gangguan major berkaitan dengan suhu yang dihadapi oleh penanam dan juga diketahui berkaitan dengan suhu penyimpanan tertentu yang pelbagai. Kajian ini bertujuan untuk mengenal pasti suhu penyimpanan yang sesuai untuk kentang premium varieti 'Lady Rosetta' dengan merujuk khusus kepada perubahan dalam kualiti, penurunan berat, jumlah gula, kanji, asid askorbik, jumlah kandungan fenolik, aktiviti memerangkap radikal, aktiviti enzim dan warna cip kentang. Varieti kentang yang dipilih telah disimpan pada lingkungan suhu yang berbeza (5, 15 dan 25°C) untuk mengenal pasti suhu penyimpanan sesuai. Keputusan menunjukkan perbezaan ketara dalam kualiti yang diuji sebagai tindak balas kepada suhu penyimpanan yang berbeza. Penyimpanan kedormanan kentang dikekalkan pada 5°C sehingga 126 hari, walau bagaimanapun, ia didapati berkaitan dengan peningkatan pengumpulan gula (2.32 g/100 g), pengurangan kanji yang cepat (13.25 g/100 g) dan prestasi pasca pemprosesan yang lemah (nilai-L, 52.00). Sebaliknya, penyimpanan kentang pada 15°C dapat mengekalkan kandungan gula lebih rendah (1.33 g/100 g) dan warna cip unggul (nilai-L, 59.33) hingga ke akhir penyimpanan. Tetapi, ia didapati berkaitan dengan peningkatan polifenol oksidase (38.47 U/g f.w) dan aktiviti peroxidase (15.25 U/100 g f.w) berbanding kentang yang disimpan pada 5°C dalam tempoh penyimpanan yang sama. Jangka hayat penyimpanan kentang yang disimpan pada 25°C telah berkurang dengan ketara disebabkan oleh pemecahan kedormanan pada hari ke-84 dan degradasi kanji (15.29 g/100 g), peningkatan pengumpulan gula (1.32 g/100 g) dan peningkatan polifenol oksidase (79.89 U/g f.w) dan aktiviti peroksidase (40.69 U/100 g f.w). Keputusan menunjukkan bahawa varieti kentang 'Lady Rosetta' sensitif kepada sejuk dan memerlukan suhu tertentu untuk penyimpanan jangka masa panjang dan prestasi pasca pemprosesan yang terbaik.

Kata kunci: Aktiviti enzim; kentang; kualiti cip; sifat fisiko-kimia; suhu penyimpanan

INTRODUCTION

Potato storage is very crucial in South Asia primarily due to poor transportation and high temperature that favor decay during the post harvest period. Physiological processes (ripening, respiration, evapo-transpiration), physical damage and microbial invasion limit the storage life of fresh produce. These factors are directly or indirectly influenced by different temperature conditions. Temperature management is considered to be the most important factor in acquiring the postharvest quality and storage life in horticultural commodities.

Low temperature slows down the enzymatic activities, hinder respiration rate, retard tomato softening and determines the final nutritional composition (Madhavi & Salunkhe 1998). Keeping horticultural commodities under low temperature storage is therefore an efficient technique to reduce post harvest losses. However, its optimum range for specific produce is critical to avoid various physiological disorders like, chilling injury, freeze injury and potato specific low temperature sweetening.

Low temperature is employed to prolong the postharvest storage of potato by extending natural dormancy through an imposed dormancy (Wiltshire & Cobb 1996). Generally in commercial storage, cured potato tubers are purposely stored at 3-5°C for seed, 6-9°C for fresh market and 10-15°C for processing (Western Potato Council 2003). The storage temperature is, however, associated with undesirable hexose sugars accumulation, also termed as low temperature sweetening (Tamaki et al. 2003).

Low temperature sweetening in potato tubers starts with in few days of storage and is characterized by the degradation of starch polymers into sucrose due to inactivation of glycolytic enzymes (phosphofructokinase and fructose-6-phosphate phosphotransferase). Sucrose is further hydrolyzed into glucose and fructose by the activity of enzyme invertases (Sonnwald 2001). Reducing sugar accumulation in potato tubers during low temperature storage is of prime industrial concern due to its participation as a substrate in Maillard reaction at elevated temperatures. The high level of reducing sugars gives rise to commercially unacceptable brown colored potato chips with the possibility of acrylamide formation (Blenkinsop et al. 2002). High sugar accumulation in potato at low temperature can be reversed to some extent by reconditioning them at increased storage temperature (>15°C) before frying (Kumar et al. 2004). At intermediate temperature, sugars are converted back into starch or metabolized as a respiratory substrate. However, the reconditioning process is cultivar dependent and does not alleviate sugars at acceptable level, especially, in case of irreversible senescent sweetening during prolonged storage (Knowles et al. 2009).

In order to maintain desirable processing qualities in selected potato variety, proper temperature management is very important during storage. It is known that different potato cultivars grown under different climate and soil conditions may respond differently to their storage conditions. It is therefore hypothesized that proper storage

temperature management would ensure the improved potato storage with intact quality attributes. Storage temperature management for the premium processing potato variety Lady Rosetta grown under indigenous conditions has never been carried out before. Changes in different quality attributes in potato under comparative temperature regimes will be advantageous for the researchers in understanding the postharvest storage physiology and for the processor to develop export quality products.

MATERIALS AND METHODS

Potato variety Lady Rosetta was harvested from Potato Research Institute, Sahiwal (Punjab, Pakistan). The variety has been selected due to its wide spread adaptability to the local conditions and superior processing quality attributes like, high dry matter and low sugar contents. The experimental material was shifted to the Postharvest Technology Laboratory, Department of Food Technology, PMAS-Arid Agriculture University Rawalpindi, Pakistan. Potatoes were washed, sorted and graded into homogenous lots and subsequently cured (15-20°C) for one week before being subjected to different analytical trials during storage. Potatoes were placed under three temperature regimes at 5°C, 15°C and 25°C with relative humidity maintained at 70±5%.

One kg potato tubers were placed in each replication, thus, 3 kg tubers were maintained in each treatment for the analytical estimations. In total, 30 kg potatoes were maintained in each treatment during the complete storage duration. These samples were fortnightly subjected to different physicochemical analyses. The set of treatments were as follows: T₁ = 5±1°C, T₂ = 15±1°C and T₃ = 25±1°C.

PHYSICOCHEMICAL, FUNCTIONAL AND PROCESSING ATTRIBUTES

Weight Loss The weight loss (%) in different experiments at specified storage interval was determined by weighing the samples with digital balance (OHAUS, Model TS4KD Florham Park, NJ, USA) and reported as percent loss in sample weight based on its initial weight.

$$\text{Weight loss (\%)} = \frac{(\text{Initial weight} - \text{Final weight})}{\text{Initial weight}} \times 100.$$

Glucose Glucose estimation was carried out by glucose test strips imported from Snack Food Association, (SFA) Arlington Virginia, USA. The color change was correlated with the color chart and the values were expressed in percentage (%). The tests were conducted in triplicate.

Total Sugar The Lane and Eynon titration method using Fehling's solution was employed for estimation of the total sugars (TS) concentrations as reported in AOAC (1990) method No. 925.35. A 10 g sample was diluted with 100 mL warm water, stirred thoroughly to dissolve all suspended

particles and subsequently filtered in 250 mL volumetric flask. 100 mL of prepared solution was transferred into a conical flask along with 10 mL of diluted HCl and boiled for 5 min. The resultant solution was cooled and neutralized with 10% NaOH and made up to volume in a 250 mL volumetric flask. The solution was titrated against Fehling's solution and readings were recorded as follows:

$$\text{Total sugar (\%)} = \frac{4.95 (\text{Factor}) \times 250 (\text{Dilution}) \times 2.5}{(\text{Weight of sample} \times \text{Titre} \times 10)}.$$

Starch Starch estimation was carried out by making the tuber sugar free by the repeated extraction with 80% iso-propanol. Tubers were dried at 70°C and then starch was hydrolyzed by 60% perchloric acid. The glucose was estimated spectrophotometrically by using anthrone reagent as described by Kumar et al. (2005).

Ascorbic Acid Ascorbic acid (AA) estimation was carried out by titrimetric method by employing 2, 6, dichlorophenol indophenol dye (redox dye) as explained in AOAC (2000) method No. 967.21. 10 g representative sample was taken in beaker and made up volume with 100 mL 3% phosphoric acid and filtered. 10 mL of filtrate was titrated with standard dye solution till pink end point. Ascorbic acid contents were quantified as follows:

$$\text{Ascorbic acid (mg/100 g)} = \frac{(\text{Dye factor} \times \text{Titration} \times \text{Volume made up})}{(\text{Weight of sample} \times \text{Volume of filtrate})} \times 100.$$

Dye Standardization Five mL of standard ascorbic acid solution was diluted with five mL of metaphosphoric acid (3%) and titrated with dye solution till pink color endured for 10 s. Dye factor was estimated (mg ascorbic acid/mL of dye) as:

$$\text{Dye factor (D.F)} = 0.5 / \text{titration}.$$

Total Phenolic Contents Total phenolic contents (TPC) in terms of gallic acid equivalent (GAE) were assessed by the Folin-Ciocalteu (FC) assay as explained by Lachmann et al. (2008) with few modifications. Tubers randomly selected were freeze dried and then extracted with 80% ethanol. Two g extract was quantitatively converted into a 100 mL volumetric flask and adjusted with 80% ethanol. In 5 mL of the sample slightly diluted with distilled water, 2.5 mL of FC and 7.5 mL of a 20% solution of sodium carbonate were added. Contents were allowed to settle for 2 h and absorbance was measured at 765 nm using a CE-2021, Spectrophotometer (CECIL Instruments Cambridge, England). Total phenolic contents were quantified by a standard calibration curve derived from the absorbance of known gallic acid concentrations (10-100 ppm). The results were articulated as mg GAE (gallic acid equivalents) per 100 g dry weight.

Radical Scavenging Activity Antioxidant activity was measured as radical scavenging activity (RSA) using the method described by Singh and Rajini (2004) that involves electron transfer reaction based assay by employing free radical 2, 2-diphenyl-1-picrylhydrazyl (DPPH). Five mg of freeze-dried potato extract was incubated with 1.5 mL of DPPH solution (0.1 mM in 95% ethanol). The reaction mixture was properly shaken and allowed to stand for 20 min under ambient temperature. Absorbance of the resultant mixture was determined at 517 nm against blank. The radical scavenging activity was determined as decrease in the absorbance of DPPH using the following equation.

$$\text{Radical scavenging activity (\%)} = 1 - \left(\frac{A_{\text{sample } 517 \text{ nm}}}{A_{\text{blank } 517 \text{ nm}}} \right) \times 100.$$

Polyphenol Oxidase Assay Enzyme extraction was carried out by the method described by Yemenicioglu (2002) with some modifications. Washed, peeled and diced potatoes were placed under -20°C before homogenate preparation. 200 g frozen potato was homogenized with 300 mL acetone and 1 g polyvinyl polypyrrolidone (PVPP) in a Waring blender. The resultant mixture was homogenized for 2 min and subsequently filtered through Whatman No. 1. Acetone powder preparation was carried out by repeated extraction and evaporation. The extraction mixture was prepared by mixing 0.4 g PVPP, 2 g acetone powder and 50 mL of cold 8.8% sodium chloride solution. The extraction was completed at 4°C temperature for 3 h under magnetic stirrer. The extract was filtered, centrifuged at 11000 g for 20 min and subsequently stored at -20°C before enzyme estimations.

Polyphenol oxidase (PPO) activity was determined by the method described by Yemenicioglu (2002). The reaction mixture contained 2 mL 0.01 M sodium phosphate buffer (pH 7.0), 0.2 mL of 0.25 M catechol and 0.3 mL enzyme extract to the total volume of 2.5 mL. The optical density (OD) of the reaction mixture was determined spectrophotometrically at 420 nm. PPO activity was calculated by the change in OD over a period of 30 s and expressed as U/g fresh weight. In spectrophotometric assay 1 U was defined as 0.001 change in absorbance per min per mL of enzyme extract.

Protein estimation was carried out by the method of Lowry et al. (1951) using bovine serum albumin (BSA) as standard. Protein standards of crude and partially purified extracts were prepared in 8.8% NaCl solution and deionized water, respectively. All the assays were carried out in triplicate.

Peroxidase Assay Enzyme extraction and protein estimation was carried out similarly as reported above. Peroxidase (POD) estimation was carried out as reported by Abbasi et al. (1998). Reaction mixture consisted of 2.1 mL, 15 mM NaKPO₄ buffer (pH6.0), 0.3 mL 1 mM H₂O₂, 0.3 mL 0.1 mM guaiacol and 0.3 mL enzyme extract to the total volume of 3 mL. The optical density (OD) of the

reaction mixture was determined spectrophotometrically at 470 nm. POD activity was estimated by the change in OD due to guaiacol oxidation over 30 s time and expressed as U/100 g fresh weight.

Chip Color Potato chips were prepared at bi-week intervals to assess processing performance of stored potatoes. Peeled tubers were sliced (1.2-1.5 mm thick) and then blanched in 1.5% NaCl solution at $85\pm 2^\circ\text{C}$ for 2 min. After pre drying the chips were fried in palm oil using electric fryer at $180\pm 5^\circ\text{C}$ for 3 min. The chip color (CCL) was correlated with British Potato Council (BPC) frying color chart and the values were recorded as approximate L-values.

STATISTICAL ANALYSIS

Data obtained as mean of three replications were analyzed by two-factor (temperature and storage duration) factorial in completely randomized design (CRD) and mean comparisons ($p\leq 0.05$) were carried out by Duncan multiple range (DMR) test using M-Stat-C statistical software as described by Steel et al. (1997).

RESULTS

WEIGHT LOSS

Increasing trend in weight loss (%) was observed at all storage temperatures. However, the rate of increase was slower in 5°C as compared to 15°C and 25°C . The effect of treatments, storage intervals and their interaction was found significant ($p\leq 0.05$) for the weight loss. Weight loss (%) remained under acceptable limit (0.58-2.81%) during the 1st month in all the treatments. However, the minimum weight loss was observed in 5°C (3.25%) followed by 15°C (8.29%) and 25°C (13.29%) on 126th, 126th and 84th days, respectively. Overall, the maximum weight loss (%) was estimated at 25°C up to 84th day of storage.

Afterward, the weight loss (%) was not determined due to shriveling and excessive sprouting, thus, rendering the tuber commercially unacceptable for industrial processing (Figure 1).

Glucose Glucose contents showed variable trends under different storage temperature with substantial initial increase followed by a steady decline at 5°C , steady increase at 15°C and steady increase with eventual decline at 25°C . The effect of treatments, storage intervals and their interaction was found significant ($p\leq 0.05$) for the glucose contents. Potato storage at 5°C showed significant increase in glucose contents as compared to other temperature regimes. This rise was paramount (842.11 mg/100 g) in 1st month followed by steady decline, however, it remained more than 2-folds in other treatments till the end of storage. Steady increase in glucose contents was witnessed at 15°C and 25°C and remained within the close range, but the rate of increase was profound in later (398.6 mg/100 g) than the former (291.7 mg/100 g) on the 70th day (Figure 2).

Total Sugars Total sugars accumulation in response to different temperature was found in consistent with glucose contents. Generally, total sugars increased in all treatments followed by a steady decline with highly significant rise estimated at 5°C . The effect of treatments, storage intervals and their interaction was found significant ($p\leq 0.05$) for the total sugars. Amongst all storage temperatures, maximum sugar contents (>3%) were estimated at 5°C during the 1st month and retained elevated sugar contents (>2.7%) till 70th day there after followed by a gradual decline. Sugar contents increased slowly under the other two temperature regimes with maximum contents identified in 15°C (1.25 g/100 g) and 25°C (1.39 g/100 g) on 126th and 70th day, respectively (Figure 3).

Starch Changes in starch contents under different temperature storage showed that general decrease with

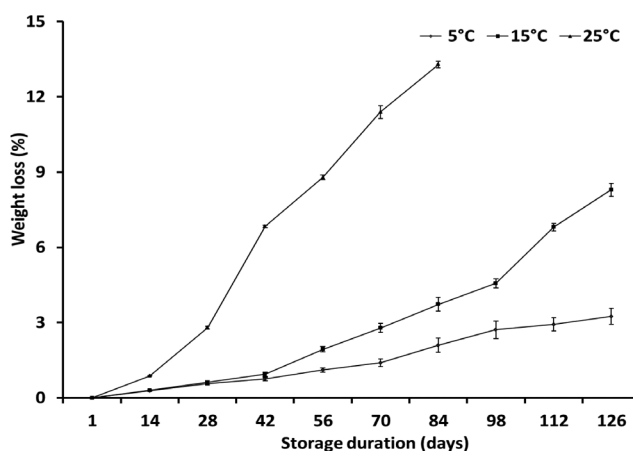


FIGURE 1. Weight loss in potato under comparative temperature storage showing minimum loss at 5°C . The vertical bars indicate standard error ($\pm\text{SE}$) of mean ($n = 3$). All means are significantly different at $p \leq 0.05$

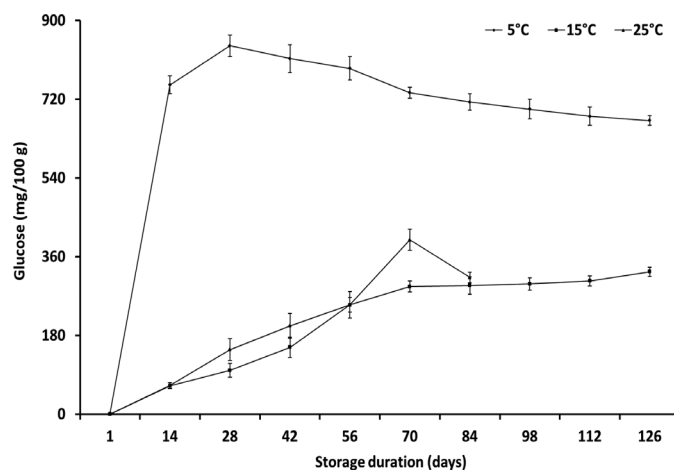


FIGURE 2. Glucose in potato under comparative temperature storage showing maximum contents at 5°C. The vertical bars indicate standard error (\pm SE) of mean ($n = 3$). All means are significantly different at $p \leq 0.05$

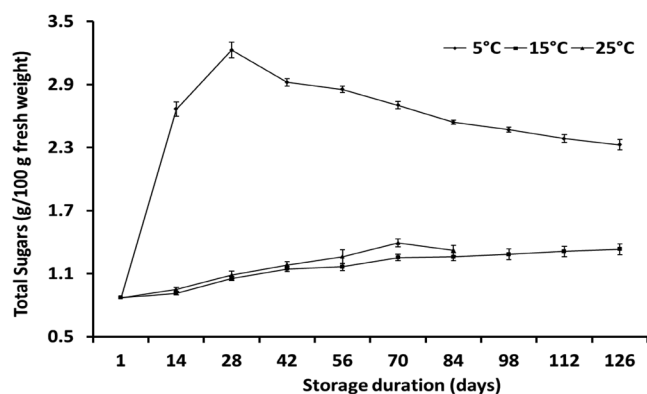


FIGURE 3. Total sugar in potato under comparative temperature storage showing maximum contents at 5°C. The vertical bars indicate standard error (\pm SE) of mean ($n = 3$). All means are significantly different at $p \leq 0.05$

the progress in storage period. The effect of treatments, storage intervals and their interaction was found significant ($p \leq 0.05$) for the starch contents. In general starch contents declined under all storage temperatures; however, minimum contents (13.25 g/100 g) were recorded at 5°C at the end of storage period. Storage at 15°C retained appreciable starch contents (17.07 g/100 g) followed by 25°C (15.29 g/100 g) and 5°C (13.73 g/100 g) till 84th day there after followed a general decline. Storage at 25°C presented small initial increase in starch contents there after followed by a gradual decline till the end of storage period. Storage at 25°C retained higher starch contents than 5°C and lower than 15°C but the commercial storage life remained only up to 12 weeks as compared to 18 weeks storage found in other two temperatures (Figure 4).

Ascorbic Acid There was decreasing trend in ascorbic acid (AA) contents in all treatments; however, the retention of ascorbic acid was inversely proportional to the storage temperature. The effect of treatments, storage intervals

and their interaction was found significant ($p \leq 0.05$) for the ascorbic acid. Amongst different temperature storage, potato tubers at 5°C retained maximum AA contents (17.45 mg/100 g) up to 126 days. However, moderate AA contents (14.43 mg/100 g) were estimated at 15°C during the same storage period. Storage at 25°C retained closely similar AA contents (14.50 mg/100 g) but the storage life last up to 84 day. AA contents at 5°C on 126th day (17.45 mg/100 g) were higher than that quantified on 56th day (16.09 mg/100 g) at 25°C (Figure 5).

Total Phenolic Contents Potato storage under all temperature regimes showed in general parabolic trend with initial incomparable increase in total phenolic contents (TPC) followed by gradual decline till the end. The effect of treatments, storage intervals and their interaction was found significant ($p \leq 0.05$) for the total phenolic contents. TPC increased in all treatments with the increase in storage duration; however, 5°C retained appreciable contents as compared to other temperature

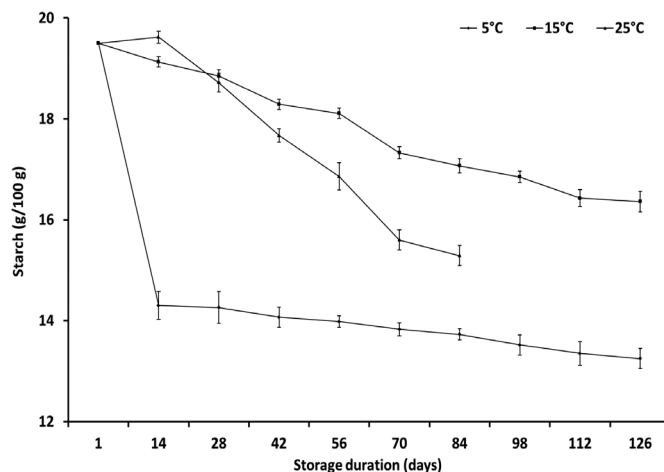


FIGURE 4. Starch in potato under comparative temperature storage maintaining maximum contents at 15°C. The vertical bars indicate standard error (\pm SE) of mean ($n = 3$). All means are significantly different at $p \leq 0.05$

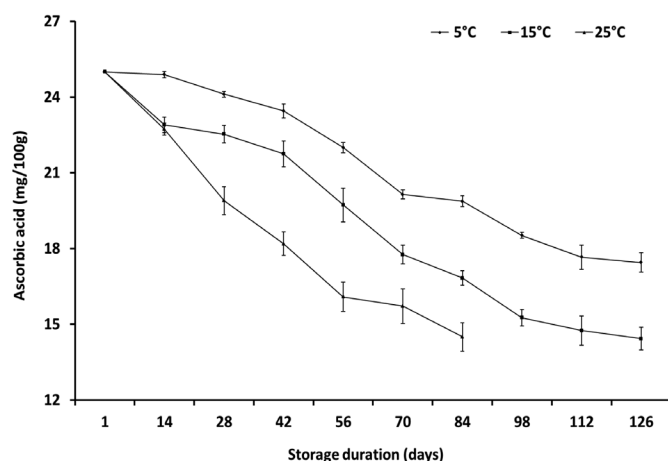


FIGURE 5. Ascorbic acid in potato under comparative temperature storage maintaining maximum retention at 5°C. The vertical bars indicate standard error (\pm SE) of mean ($n = 3$). All means are significantly different at $p \leq 0.05$

storages. Potato storage at 25°C showed initial increase in TPC up to 1st month storage followed by major decline (80.52 mgGAE/100 g) by 84th day. TPC increased continuously at 15°C till 70th day, thereafter, presented considerable decline (121.70 mgGAE/100 g) by the 126th day. Maximum increase (157.80 mgGAE/100 g) in TPC was observed at 5°C on 98th day followed by decline during the last month of storage (Figure 6).

Radical Scavenging Activity In general influence of different temperatures on radical scavenging activity (RSA) showed initial increase followed by a gradual decrease with the progression in storage period. The effect of treatments, storage intervals and their interaction was found significant ($p \leq 0.05$) for the radical scavenging activity. Significant increase in radical scavenging activity (41.7-43.4%) witnessed in all treatments till the 1st month. Afterward, the RSA declined at 25°C

(24.27%) while continued to increase at 5°C (48.8%) and 15°C (46.93%) till the 70th day storage. RSA showed considerable decline at 15°C (28.23%) during the rest of storage period. In contrast, potato storage at 5°C (41.50%) followed moderate onward decline till the end (Figure 7).

Polyphenol Oxidase Activity In general polyphenol oxidase (PPO) activity in potato tuber was found proportional to their storage temperatures. The effect of treatments, storage intervals and their interaction was found significant ($p \leq 0.05$) for the polyphenol oxidase activity. In general, lowest PPO activity was observed at 5°C with minimum activity (18.50 U/g f.w) estimated on 70th day followed by slight increased activity (20.83 U/g f.w) till the end of storage. PPO activity showed overall steady and comparatively swift increases in potato stored at 15°C and 25°C, respectively. Storage at 15°C showed low activity

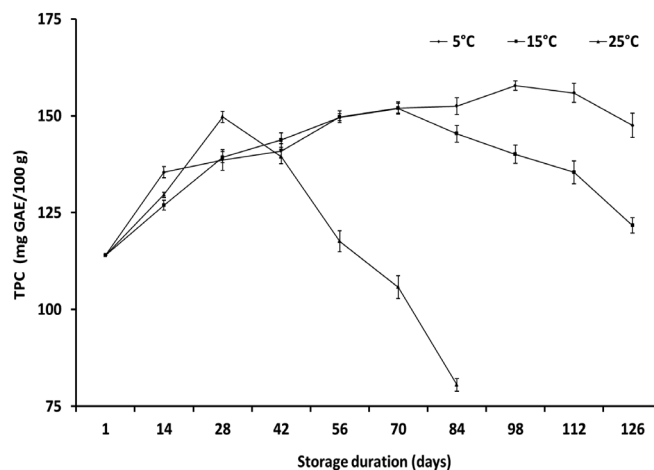


FIGURE 6. Total phenolic contents in potato under comparative temperature storage showing maximum retention at 5°C. The vertical bars indicate standard error (\pm SE) of mean ($n = 3$). All means are significantly different at $p \leq 0.05$

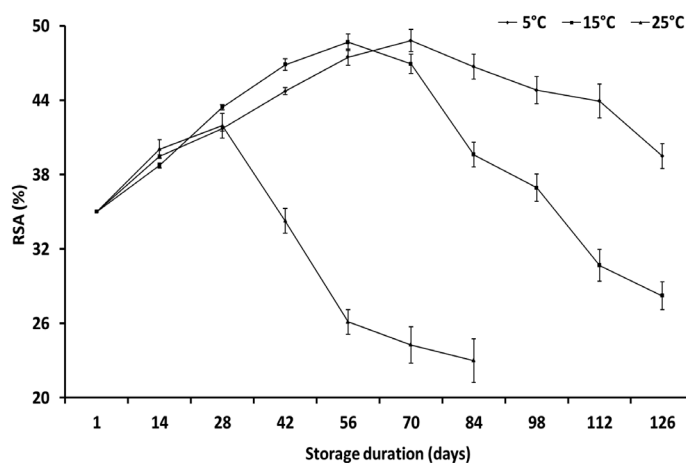


FIGURE 7. Radical scavenging activity in potato under comparative temperature storage showing highest activity at 5°C. The vertical bars indicate standard error (\pm SE) of mean ($n = 3$). All means are significantly different at $p \leq 0.05$

(30.0 U/g f.w) till 84th day afterward increased by the end of storage (38.5 U/g f.w). Overall, maximum PPO activity was estimated in potato stored at 25°C with highest value (79.89 U/g f.w) recorded on 84th day of storage (Figure 8).

Peroxidase Activity General trend regarding POD activity showed initial decrease followed by eventual increase in T_1 and T_2 , while continuous increase was observed in T_3 during the storage. The effect of treatments, storage intervals and their interaction was found significant ($p \leq 0.05$) for the polyphenol oxidase activity. Potato storage at 5 and 15°C showed an initial increase followed by final decrease till the end. The decline in POD activity (8.2 U/100 g) was more pronounced at 5°C on 70th day afterward increased closer to the activity estimated on the 1st day of storage. Storage of tubers at 15°C also exhibited slight decrease in activity (9.6 U/100 g) on 56th day, followed by increased activity (15.25 U/100 g) estimated on 126th day. Potato

tubers stored at 25°C attained maximum POD activity (40.69 U/100 g) by the end of storage period. This increase in POD activity started after 1st month storage and 3-folds increase of the initial value was observed on 84th day (Figure 9).

Chip color Chip Color (CCL) estimated in terms of approximate L-value under different temperature showed general decrease with the increase in storage period. The effect of treatments, storage intervals and their interaction was found significant ($\alpha=0.05$) for the potato chip color. Storage at 5°C presented lowest CCL value (L-value 49.00) between 28-56th days. CCL values subsequently followed slight increase (L-value 52.00) by the end of the storage period. Storage at 25°C retained appreciable CCL values (L-value 63.00) till 42nd day. Afterward, it exhibited 20% decline on the 84th day with estimated CCL value (L-value 52.00) found almost similar to that estimated at 5°C on 126th day. Significant retention of CCL values were

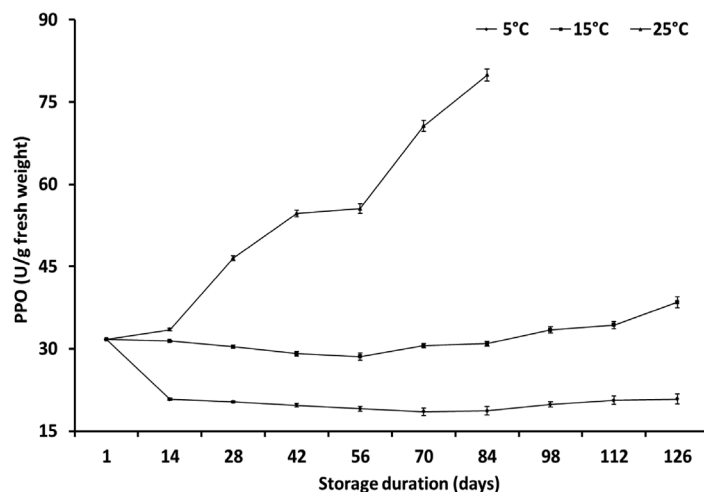


FIGURE 8. Polyphenol oxidase in potato under comparative temperature storage showing lowest enzymatic activity at 5°C. The vertical bars indicate standard error (\pm SE) of mean ($n = 3$). All means are significantly different at $p \leq 0.05$

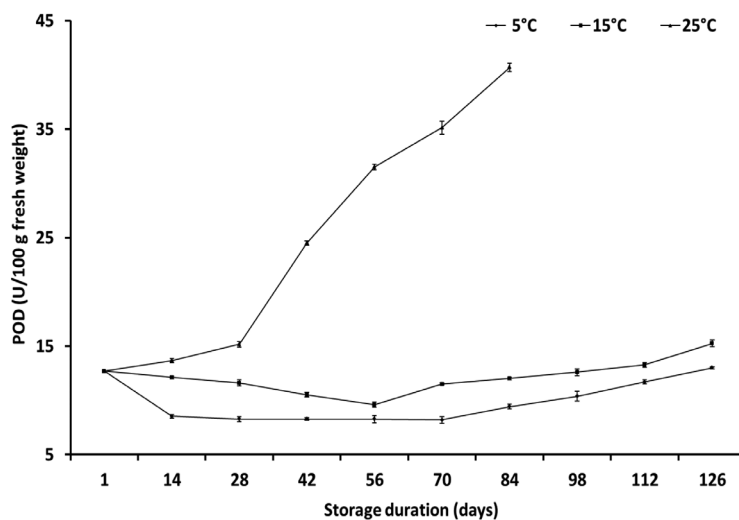


FIGURE 9. Peroxidase in potato under comparative temperature storage showing lowest enzymatic activity at 5°C. The vertical bars indicate standard error (\pm SE) of mean ($n = 3$). All means are significantly different at $p \leq 0.05$

estimated at 15°C during most of the storage period with lowest CCL value (L-value 59.33) reported on 126th day of storage (Figure 10).

DISCUSSION

Weight loss (%) in potato during the post harvest storage is associated with moisture loss due to evapotranspiration and dry matter loss due to respiration and sprouting (Tester et al. 2005). Respiration is the index of active metabolism during storage and is characterized by oxygen consumption and carbon dioxide and heat production. Low temperature storage lowers the respiration rate and enzymatic activities, prevents potato sprouting by prolonging natural dormancy through induced dormancy. Ghazavi and Houshmand

(2010) studied the respiration rate and weight loss (%) in potato at different storage temperatures (5, 10 and 15°C) and found minimum respiration rate and weight loss (%) at 5°C. Our results showed direct relationship between the storage temperature and weight loss (%) which might be due to slower respiration rate and enzymatic activities (estimated in the present study) at 5°C. Increased weight loss at 15 and 25°C storage might be associated with their high respiration rate. However, pronounced weight loss at 25°C might be due to the extra energy required for the sprouts development. Decreased weight loss under low temperature storage has also been reported by other researchers in potato (Kyriacou et al. 2009), tomato (Javanmardi & Kubota 2006) and citrus (Mahajan et al. 2005).

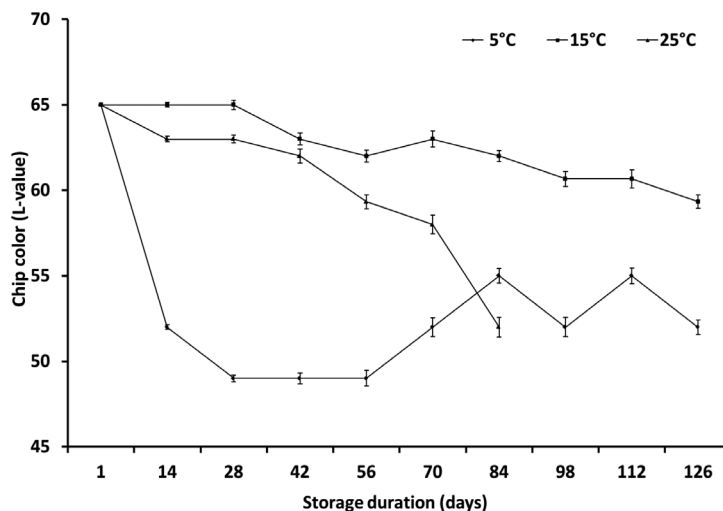


FIGURE 10. Chip color in potato under comparative temperature storage showing highest value at 15°C. The vertical bars indicate standard error (\pm SE) of mean ($n = 3$). All means are significantly different at $p \leq 0.05$

Low temperature storage in potato is associated with reducing sugar accumulation predominantly present in the form of glucose and fructose. Sugar accumulation is negatively correlated with the chip color and also reported to be the major precursor of acrylamide formation during processing (Amrein et al. 2004). Our results showed that influence of storage time on glucose contents was less pronounced compared to that of storage temperature. Significant initial increase in glucose contents at 5°C confirmed the previously reported findings by Knowles et al. (2009) who observed elevated reducing sugar in different potato cultivars under low temperature during 1st month storage. The presence of moderate glucose contents at intermediate temperatures (15°C, 25°C) confirmed the findings reported by Kyriacou et al. (2009) who presented low sugar contents in potato above 10°C storage. In the present study low glucose accumulation was estimated at 15 and 25°C, however, the postharvest storage life was significantly higher in former (126 days) than later (84 days) storage temperatures. The ultimate decline in glucose contents at 25°C might be due to its utilization as respiratory substrate at the onset of sprouting and tuber senescence, has also been reported by Kyriacou et al. (2008).

Interestingly, potato tuber exhibits increased sugars accumulation at wide temperature range due to starch degradation at elevated temperature and cold sweetening at low temperatures. Hence, the optimum storage temperature for particular potato variety is very important for prolonged storage. Total sugar contents present in potato are primarily in the form of sucrose, glucose and fructose due to starch degradation (Hajirezaei et al. 2003). These sugar contents are metabolized during tuber respiration along with their possible participation in Maillard reaction during processing. Although sucrose does not directly participate in Maillard reaction but

contributes to chip color development due to its hydrolysis during frying (Amrein et al. 2004). Endo et al. (2006) compared the sugar accumulation in some potato varieties under different temperature regimes (2°C, 6°C, 8°C, 10°C and 18°C) and reported maximum sugar contents below 8°C. In our study, significant sugar accumulation in T_1 (5°C) might be due to the rapid conversion of starch into sucrose which afterward hydrolyzed into glucose and fructose due to higher invertase activities. Steady decline in total sugars might be due to the substrate oxidation during tuber respiration, which has also been reported by Sonnewald (2001). Final decline at the end of storage in total sugars was comparatively rapid than the glucose contents. This might be attributed to the synchronized glucose addition due to sucrose cleavage mediated through vacuolar invertase activity, as described by Junker et al. (2006).

Starch and sugars are the principal chemical components in potato tubers influenced by low temperature storage mediated through specific enzymes. Nourian et al. (2003) studied the quality changes in potato at different storage temperatures and found that starch contents decreased with the decrease in storage temperature and increase in storage time. Our results presented significant decline in starch contents at lowest (5°C) and highest (25°C) storage temperatures. Significant reduction in starch content at 5°C might be associated with the inactivation of glycolytic enzymes, higher invertase activity (Sonnewald 2001) and found largely a function of storage temperature than the storage time. Decrease in starch contents at 25°C after two month storage till the end (84th day) might be due to the sufficient energy required by the growing sprouts, has also been observed by Farre et al. (2001). Storage of potato tubers at intermediate storage temperature (15°C) retained appreciable starch contents and maintained the tuber dormancy up to 126 days. However, storage at 15°C

was found associated with the increased weight loss as compare to that of storage at 5°C.

Significant reduction in AA content has been observed in potato postharvest storage with the increase in storage temperature (Nourian et al. 2003) and time (Blenkinsop et al. 2002). The present investigation showed that the retention of AA contents in potato during their postharvest storage is equally associated with their storage temperature and time. Storage at 5°C retained highest AA contents during most of the storage period; however, decline during final weeks might be due to their oxidation into dehydro-ascorbic acid under prolonged storage as also reported by Davies et al. (2002). Lowest retention of AA contents at 25°C might be due to their oxidation in the presence of molecular oxygen mediated through enzyme ascorbate oxidase thus, confirmed the findings of Saari et al. (1995). General response of AA contents to prolonged potato storage also confirmed the findings of Rivero et al. (2003) and Tamaki et al. (2003) who reported considerable reduction of ascorbic acid in potato in response to time and temperature variables.

Low temperature storage of potato is widely practiced technique for high TPC retention by preventing their oxidation due to the inactivation of enzyme polyphenol oxidase (Barberan & Espin 2001). Our results showed significant retention of TPC at 5°C during most of the storage period, has also been observed by Christie et al. (1994) who reported increased phenol biosynthesis under low temperature storage. Decline in TPC at 5°C during the last weeks of storage might be associated with the tuber stress due to free radicals formation at the onset of senescent sweetening (Kumar 2011). Significant decline in TPC at 25°C after 1st month storage might be due to the initiation of tuber sprouting (Saltveit 2000). Consequently, it triggered the polyphenol oxidase activities, thereby, leading to the TPC decline. Initially, appreciable TPC contents were retained at 15°C however their decline after 70th day might be found associated with their increased PPO activities which have also been reported by Madiwale et al. (2011).

Potato considered as substantial source of these antioxidant compounds mostly present as ascorbic acids, polyphenols and anthocyanins depending upon the type and color of potato varieties (Lachman et al. 2008). Appropriate temperature management in potato storage reported to enhance antioxidant activity with stumpy postharvest losses. Lewis et al. (1998) reported increased phenolic and anthocyanin contents (high antioxidant activity) in colored potato varieties under low temperature storage. In the present study, non-enzymatic antioxidant activity was determined as DPPH radical scavenging activity which primarily corresponded to the presence of ascorbic acids, phenolic contents and flavonoids. The RSA pattern in potato under all temperature storage expressed consistent pattern with their phenolic and ascorbic acid contents with minor deviations. The initial increase in RSA activity might be due to ample ascorbic acid contents which relayed with

the increased accumulation of phenolic contents along the storage period (Madiwale et al. 2011). However, potato under different temperature expressed significant variation in their RSA at the end of their storage. Storage at 5°C maintained highest radical scavenging activity during most of time owing to its ample ascorbic acids and phenolic contents. The decline in activity observed during the last month might be attributed to the phenomenon of senescence sweetening (Kumar 2011) and ascorbic acids oxidation (Davies et al. 2002) under prolonged cold storage. Significant decline in RSA at 15°C and 25°C after 28th and 56th day, respectively, might be due to their loss of phenolic and ascorbic acid contents as also observed in the present study.

Enzymatic browning causes nutritional and sensorial loss in horticultural commodities and primarily mediated through the activities of the group of enzymes termed as Poly phenol oxidases (PPO). PPO activity increases with the increase in physiological stages and becomes highly pronounced during senescence and stress conditions hence a significant index of storage life in horticultural produce. Nourian et al. (2003) studied changes in quality attributes of potato tubers stored under different temperature regimes and concluded that PPO activity in potato tuber is directly proportional to their storage temperature. Amongst different temperatures studied he found decrease and increase in PPO activity at 4°C and 20°C temperature, respectively. Our results concluded that amongst different temperature studied, storage at 5°C efficiently maintained low PPO activity, consequently, improved the storage stability of potato as compare to those placed at intermediate (15°C) and ambient temperature (25°C). The presence of substantial phenolic content in potato tubers stored at low temperature (5°C) also supported this argument. Zorzella et al. (2003) also reported decrease in PPO activity at low temperature storage in different potato cultivars. In our study, storage at 25°C resulted in rapid increase in PPO activity after two weeks and continued at progressive rate till the end of storage. Highly significant activity especially after 56th day might be due to the rapid oxidation of phenolic contents in the tubers close to the onset of sprouting thus, found in line with the findings of Saltveit (2000).

POD and PPO are considered as the major enzymes in horticultural commodities responsible for the quality loss due to phenolic dilapidation (Barberan & Espin 2001). Aydin and Kadioglu (2001) reported increased POD activity in fruits and vegetables under stress conditions and with the progression in their physiological stages i.e. senescence. Our results showed significant increase in POD activity after 1st month onward till the onset of sprouting at 25°C which confirmed the above reported observations. Vitti et al. (2011) studied enzyme kinetics in different potato varieties at 5°C and 15°C and reported lower POD activity in former than in the later temperature storage which has also been identified in the present investigation. Lowest estimated POD activity at 5°C in the present study might be associated with the low substrate availability. Similar

trend in PPO and POD activities in the present study under different temperatures also confirmed the synergistic effect between these two enzymes which have also been reported by Subramanian et al. (1999).

Chip Color is a vital factor for consumer acceptance and is primarily associated with their reducing sugar contents (Tamaki et al. 2003). Storage at 15°C and 25°C temperature showed minor tendency of decline in CCL value over storage period in contrast the decline was rapid at 5°C within 1st month of storage. It was evident from our results that reducing sugars sharply increased at 5°C with in 1st week and corresponded with the significant decline in CCL values during the same period. This inverse relationship between reducing sugars and CCL has also been cited by different researchers like Kyriacou et al. (2009) and Tamaki et al. (2003). Storage at 15°C presented remarkable CCL values (approximate L-values) during most of storage period in potato chips and found superior to those placed under other temperature (5°C, 25°C) which might be due to their low corresponding reducing sugar contents. Appreciable CCL values were estimated at 25°C temperature till 42nd day storage followed by considerable decline till the end of storage. This significant decline in CCL values at 25°C might be associated with starch depletion, high sugar contents and possible participation of dehydro-ascorbic acid in chip browning which has also been reported by Blenkinsop et al. (2002).

CONCLUSION

This study showed that different physico-chemical, functional and enzymatic activities were significantly affected by different temperature regimes. Significant storage-associated correlations were identified in starch-sugar metabolism and total phenolics-radical scavenging activity under all storage temperatures. Enzyme kinetics during the storage period was also affected by physiological stages like senescence and sprouting. Loss of ascorbic acids and phenolic contents would constitute nutritional loss, specifically, at elevated storage temperatures. Potato storage at 25°C had low reducing sugar but found unacceptable due to shriveling and earlier dormancy break. In contrast, storage at 5°C maintained the tuber dormancy till the end of storage period but found associated with increased sugar contents and poor chip color. Storage at 15°C was found efficient to prevent dormancy break up to four month with desirable quality attributes. It was further concluded that Lady Rosetta is cold sensitive variety and rational combination of storage temperature and storage time is a critical factor for its efficient postharvest management.

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