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Studies on quality and vase life of cut *Gerbera jamesonii* cv. 'Balance' flowers by silver nanoparticles and chlorophenol

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Abstract

Cut gerbera flowers are sensitive to microbial contamination and have a short vase life. Silver nanoparticles are used in various applications as an antimicrobial agent. An experiment was conducted to determine the effect of different concentrations of SNP and chlorophenol to extend the vase life and postharvest quality of gerbera (*Gerbera jamesonii* cv. 'Balance') cut flowers. Cut gerbera flowers were kept in solutions containing 0, 5, 10 and 20 mg l^{-1} SNP and/or 0, 5 and 10 mM chlorophenol for 24 hr; then held in vase solution containing 250 mg l^{-1} 8-hydroxyquinoline sulphate and 3% sucrose. The maximum vase life (16.33 days) was observed in flowers held in solution containing 10 mg l^{-1} SNP. The 5 mg l^{-1} SNP plus 10 mM chlorophenol and 10 mg l^{-1} SNP plus 5 mM chlorophenol inhibited bacterial growth in the vase solution. The minimum fresh weight loss (6.48gr) during the vase period was observed for flowers kept in solution containing 20 mg l^{-1} SNP. The results revealed that SNP and chlorophenol have the potential to extend vase life and enhanc the postharvest quality of cut gerbera cv. 'Balance' flowers.

Key words

Bacterial contamination, Chlorophenol, Gerbera jamesonii, Silver nanoparticles, Vase life, °Brix

Introduction

Gerbera (*Gerbera jamesonii*) belongs to Asteraceae family. It is a perennial tropical plant, which is well known for its rich flower colours and shapes and is one of the ten most popular cut flowers in the world. Gerbera has short vase life and is sensitive to microbial contamination at the stem end and in the preservative solution (Balestra *et al*., 2005; Liu *et al*., 2009). Microbial contamination causes stem end blockage, imbalance between water uptake and water loss and finally wilting and short vase life (Van Doorn, 1997; Balestra *et al*., 2005). Water balance is one of the main factors which determines the quality and longevity of cut flowers (Lu *et al*., 2010). Reduced water uptake, caused by xylem blockage and enhanced transpiration are the major reasons for wilting (Halevy and Mayak, 1981; Williamson and Milburn, 1995; Van Doorn, 1997). Stem end blockage in cut flowers is classified as microbial contamination due to living bacteria and their waste products (Van Doorn, 1997; Da Silva, 2003), physical wound because of air emboli (Van Meeteren *et al*., 2006) and physiological injury (Loubaud and Van Doorn, 2004; He *et al*., 2006). Nowadays, different antiseptics are used to extend the vase life of cut flowers; that two of these are silver nanoparticles and chlorophenol (Serilong and Buanong, 2007). Silver ions are known as microorganism's growth inhibitor agent (Feng *et al*., 2000; Liu *et al*., 2012). They strongly inhibit bacterial and other microorganisms (Jiang *et al*., 2004; Furno *et al*., 2004). Use of silver nanoparticles as a pulse and continuous treatment for cut flowers is relatively new (Liu *et al*., 2009; Solgi *et al*., 2009) and its importance as an antibacterial agent has been demonstrated (Alt *et al*., 2004; Morones *et al*., 2005).

Surface area to volume ratio in silver nanoparticles is high among other silver compounds, thus silver nanoparticles formulations provide proper contact with microorganisms and are highly effective germicides (Rai *et al*., 2009). silver nanoparticles releases silver ion (Ag^+) (Lok *et al*., 2007), which has been reported to interact with cytoplasmic components and nucleic acids, to inhibit respiratory chain enzymes and to interfere with

membrane permeability (Russell and Hugo, 1994; Park *et al*., 2005; Lu *et al*., 2010). Silver ions interact with sulfydryl (-SH) groups of proteins as well as with DNA bases leading either to inhibition of respiratory processes or DNA unbinding (Batarseh, 2004). Moreover, Ag ions is used as silver thiosulfate, effectively inhibits ethylene-mediated processes; such as flower senescence and abscission (Altman and Solomos, 1995; Ichimura *et al*., 2008). Ag ions has positive effect on plant stem hydraulic conductivity (Van Leperen, 2007). Positive effect of silver nanoparticles as a novel agent to extend vase life of gerbera and some other ornamental plants has been demonstrated (Kim *et al*., 2005; Solgi *et al*., 2009; Liu *et al*., 2009). Chlorophenol is a compound which inhibits accumulation of phenolic and antioxidant compounds. Very little information is available about the effect of chlorophenol on the vase life of cut flowers. However, the use of chlorophenol is becoming increasingly widespread in extending the vase life of cut flowers (Serilong and Buanong, 2007). Van Doorn and Nicholas (2002) reported that P-chlorophenol can control phenolic enzymes in cut *Chrysanthemum* flowers. The present study investigated the effects of silver nanoparticles and chlorophenol treatments on improving the postharvest quality and extending vase life of cut gerbera (*Gerbera jamesonii* cv. 'Balance') flowers.

Materials and Methods

Experiment design and treatments : Cut gerbera (*Gerbera jamesonii* cv. 'Balance') flowers were obtained from plants grown in the Plant and Flower Centre in Mahallat city, Iran. These were immediately made to stand in buckets and transported to the postharvest laboratory. Buckets containing flower stems were covered with a plastic film shroud to minimize moisture loss during transportation. In laboratory, stems were re-cut under 4°C deionized water to ~50 cm length to remove air emboli. The flowers were selected for uniformity of size, colour and freedom from any defects.

The experimental design was a randomized completely blocks design (RCBD) with a factorial arrangement of treatments containing four silver nanoparticles concentrations (0, 5, 10 and 20 $mg\,l^{-1}$) × three chlorophenol concentrations (0, 5 and 10 mM) × twelve treatments × three replications × 36 plots. In each plot, four cut gerbera flowers were placed into 1000 ml vase filled with 250 ml of preservative solutions including the aforementioned matters. Then, these cut gerbera stems were placed into 1000 ml pots filled with 500 ml of preservative solutions supplemented with 3% sucrose and 250 mgl^{-1} 8-hydroxyquinoline sulphate. Distilled water was used as control. The outer surface of the vases was covered with sheets of paper to minimize the negative effect of light on silver nanoparticles. The flowers were kept in a vase life (controlled environment) room under the following conditions: 20 ± 2°C, relative humidity of 70-75%, 15-20 $\mu molm^{-2}s^{-1}$ light intensity (cool white florescent tubes) and a daily light period of 12 hrs.

Flower diameter decreasing index : Flower diameter was measured with a digital caliper (Guanglu) as the following expressions: (the biggest diameter of the flower + the perpendicular diameter to it ÷ 2) every other day, they were signed as D_1, D_3,..., D_L for every flower. D represents "diameter" and the number shows the day, L represents the last day of vase life. Then according to this formula ($D_3/D_1+D_5/D_3+\ldots+D_L/D_{L-2}= X$). Flower diameter decreasing index was calculated. After that, X was divided by the number of ratios; the average is flower diameter decreasing index. The first measurement was done exactly after the pulse treatment and the last one was done at the last day of vase life.

Solution uptake : In order to determine the evaporation of vase solutions, 4 dishes with 500 ml distilled water was placed between the dishes containing cut flowers. The content of dishes were weighed on the last day of each plot's vase life, solution uptake was determined for each plot as the following expressions:

$$\text{Water uptake } (ml\,g^{-1}\text{ f.wt.}) = \text{reduced content of solution on last day of vase life} + \text{surface evaporation of last day/flower fresh weight at the first day} \times 100$$

Fresh weight loss : Fresh weight was measured with a digital balance (Sartorius TE 1502S). The first measurement was done just after the pulse treatment and the last measurement was recorded on the last day of vase life. Then, the last weight was subtracted from the first one; their difference represents fresh weight loss.

Vase life : Vase life of the cut stems was assessed daily. The end of vase life is defined, taking into consideration, visible wilting and stem bending more than 90° (He *et al*., 2006).

Bacterial counting : For determination of the number of bacterial colonies in vase solutions, 24 hr after pulse treatment, 2 ml of vase solution was sampled from each vase and then diluted with 2 ml of 0.9% sterile normal saline. Liquid extract (0.1 ml) was spread on nutrient agar plates and bacterial colonies were enumerated after incubation for 24 hr at 37°C (Liu *et al*., 2009; Lu *et al*., 2010). All bacterial colonies counting were replicated three times.

Final day °Brix (stem's sucrose percent) : The final day °Brix was measured on the last day of vase life using handheld refractometer (Atago N-1α model).

Total protein content of petals : On 5th day of vase life, one cut flower from each pot was used for determination of total protein content of petals. It was measured based on the Kjeldahl digestion method for the quantitative determination of nitrogen; then the results were multiplied with 6.25 and protein content of petals was calculated.

Statistical analysis : Data were subjected to analysis of variance

in MSTATC statistical software and means were compared by the least significant difference (LSD) test at 0.05 and 0.01 probability level.

Results and Discussion

In this study, different doses of silver nanoparticles and chlorophenol were used as the main sources of variation. Based on the results, silver nanoparticles and chlorophenol could extend the vase life of cut gerbera (*Gerbera jamesonii* cv. 'Balance') flowers. The characteristics studied were flower diameter, loss of fresh weight, vase life, bacterial colonies counting, final day °Brix and solution uptake and total protein content in petals (Table 1). Data revealed that there were differences in the effect of the different concentrations of silver nanoparticles, chlorophenol and interaction between them.

Data analysis showed that the effect of different concentrations of silver nanoparticles, and silver nanoparticles in combination with chlorophenol were significant on flower diameter decreasing index ($p \leq 0.05$) (Table 2). Mean comparison of the effect of silver nanoparticles and silver nanoparticles + chlorophenol on the flower diameter revealed that maximum flower diameter decreasing index (1.019) rather than control (0.961) was obtained in cut flowers, treated with 10 mM chlorophenol in combination with 10 mg l^{-1} silver nanoparticles (Table 1). Enhancement in flower diameter decreasing index was due to anti-respiratory effect of silver nanoparticles. Total, anti-respiratory factors can delay flower diameter. Makvandi *et al*. (2011) reported the positive effect of silver nanoparticles on flower opening index of *Alesteromeria hybrida*. Moreover, silver nanoparticles treatment decreased flower opening index between 2-8 mm. The results showed that 5 mg l^{-1} silver nanoparticles was more effective rather than chlorophenol treatment at different levels (Table 1). These results are in accordance with the results obtained by Hashemabadi (2012). SNP is a new material that affects on control of microbial population and ethylene production in *Dianthus* cut flowers. Some compounds such as 1-MCP and STS reduce respiration rate by delaying climacteric respiration peak, thus production of ATP decrease. Serilaong and Buanong (2007) reported that bud opening in cut rose was fastened by pulsing the flowers with 10 mM of chlorophenol. Non-pulsed flowers had lowest bud opening compared to that of other treatments. In control flowers, uptake of carbon source from conservative solution have reduced due to the vessel blockage (Serilaong and Buanong, 2007). Flower opening may be due to combination of sugar uptake and degradation of various polysaccharides (Yamane *et al*., 1991).

Analysis of variance showed that the most effective treatment on vase solution uptake was chlorophenol ($p \leq 0.05$); silver nanoparticles alone and silver nanoparticles in combination with chlorophenol showed less efficiency (Table 2). Mean comparison showed that C_1 (0mM chlorophenol) with 3.94 ml g^{-1} f.wt. had significant effect (Fig. 1) and also, 20 mgl^{-1} silver nanoparticles in combination with 0 mM chlorophenol improved solution uptake to the extent of 4.42 ml g^{-1} f.wt. rather than the control (3.62 ml g^{-1} f.wt.), but according to analyze of variance, the interaction between silver nanoparticles and chlorophenol wasn't

Table 1 : Effect of silver nanoparticles and chlorophenol on flower diameter, vase life, total protein of petal, bacterial colonies and Brix degree of *Gerbera jamesonii* cv. Balance

Treatments	Flower diameter decreasing index	Vase life (day)	Bacterial colonies in vase solution (log^{10} CFU ml^{-1})	°Brix on final day (% saccharose)	Total protein content of petal (%)
C_1 (0 mM chlorophenol)	0.976	15.16^{a}	9.66^{a}	11.20^{a}	17.466^{b}
C_2 (5 mM chlorophenol)	0.990	11.29^{b}	3.41^{b}	12.04^{a}	23.450^{a}
C_3 (10 mM chlorophenol)	0.979	11.54^{b}	10.41^{a}	11.53^{a}	17.466^{b}
N_1 (0 mg l^{-1} silver nanoparticles)	0.969^{b}	10.38^{b}	27.55^{a}	12.78^{a}	18.566^{bc}
N_2 (5 mg l^{-1} silver nanoparticles)	0.977^{ab}	12.83^{ab}	2.00^{b}	11.62^{a}	19.400^{b}
N_3 (10 mg l^{-1} silver nanoparticles)	0.993^{a}	14.22^{a}	0.22^{b}	12.10^{a}	23.288^{a}
N_4 (20 mg l^{-1} silver nanoparticles)	0.987^{a}	12.77^{ab}	1.55^{b}	9.87^{a}	17.500^{c}
C_1N_1	0.961^{de}	14.00^{a}	36.66^{a}	5.69^{bc}	11.900^{e}
C_1N_2	0.976^{bcde}	14.50^{a}	0.33^{c}	9.45^{c}	14.400^{e}
C_1N_3	0.985^{bcde}	16.33^{a}	0.33^{c}	10.15^{bc}	26.066^{b}
C_1N_4	0.982^{bcde}	15.83^{a}	1.33^{c}	11.95^{bc}	17.500^{d}
C_2N_1	0.988^{bcd}	$9.5o^{a}$	7.66^{b}	11.70^{bc}	26.300^{b}
C_2N_2	0.992^{abc}	10.00^{a}	5.66^{bc}	10.46^{bc}	29.400^{a}
C_2N_3	0.976^{bcde}	14.66^{a}	0.00^{c}	14.01^{ab}	17.500^{d}
C_2N_4	1.003^{ab}	11.00^{a}	0.33^{c}	11.98^{bc}	20.600^{c}
C_3N_1	0.958^{e}	9.00^{a}	38.33^{a}	13.35^{bc}	17.500^{d}
C_3N_2	0.964^{cde}	14.00^{a}	0.00^{c}	14.95^{a}	14.400^{e}
C_3N_3	1.019^{a}	11.66^{a}	0.33^{c}	12.13^{bc}	26.300^{b}
C_3N_4	0.977^{bcde}	11.50^{a}	3.00^{bc}	13.28^{d}	14.400^{e}

Values in each row that are followed by the same letter are not significantly different by LSD test ($pd \leq 0.05$)

Table 2 : Analysis of variance on the effect of silver nanoparticles and chlorophenol on flower diameter, loss of fresh weight, vase life, solution uptake, bacterial colonies, Brix degree and total protein in petals of *Gerbera jamesonii* cv. Balance

Source of variation	df	Mean of square						
		Flower diameter decreasing index	Fresh weight loss (g)	Vase life (day)	Solution uptake (ml g^{-1} f.wt.)	Bacterial colonies in vase solution (log^{10} CFU ml^{-1})	°Brix on final day (%)	Total protein content of petal (%)
Chlorophenol (C)	2	0.001^{ns}	8.632^{ns}	56.438^{**}	3.012^{*}	177.250^{**}	2.127^{ns}	128.714^{**}
silver nanoparticles (N)	3	0.001^{*}	45.304^{*}	17.463^{*}	0.820^{ns}	1561.00^{**}	13.838^{ns}	57.282^{**}
C × N	6	0.001^{*}	7.664^{ns}	7.512^{ns}	0.261^{ns}	250.250^{**}	25.563^{**}	119.545^{**}
Error	22	0.001	9.636	3.866	0.346	8.737^{**}	5.122	3.242
Total	36	-	-	-	-	-	-	-
cv	-	1.702	32.411	22.93	21.74	177.49	25.87	9.145

**: Significant at ∞= 1%, *: Significant at ∞= 5%, ^{ns}: Not significant

significant (Table 2). Positive effect of silver nanoparticles is due to its antimicrobial effect and inhibition of stem-end blockage in cut flowers. Results of current paper confirmed the studies of Liu *et al.* (2009), Basiri *et al*. (2011) and Hashemabadi (2014). Serilong and Buanong (2007) studied the effect of chlorophenol on vase life of cut rose (*Rosa hybrida* 'American Gala') and reported that chlorophenol pulse treatment enhanced water uptake and decreased loss of fresh weight and blueing symptoms. These researchers showed that pulsing flowers with 10 mM of chlorophenol significantly induced water uptake to a higher level than other treatments. Similar finding was obtained by Van Doorn and Nicolas (2002) in cut chrysanthemum flowers. Shabani *et al*. (2011) investigated the effect of different concentrations of silver nanoparticles on *Strelitzia reginae* and found that silver nanoparticles can remove stem-end microorganisms and improve solution uptake and vase life. Studies of Lu *et al*. (2010) on cut rose flowers indicated that the amount of water uptake and water loss by control flowers was greater than flowers with 50 and 100 mgl^{-1} NS pulse treatments. These researchers also showed that leaf water content for the pulse treatments with 50 and 100 mgl^{-1} NS were higher than control. In control plants, water reduced more rapidly during vase life period. Water deficit in a cut stem standing in vase solution develops when the rate of water uptake is lower than the rate of transpiration. Water stress can be delayed by decreasing the rate of transpiration (Van Doorn, 1997).

Results showed that the loss in fresh weight of cut flower's was significantly affected by silver nanoparticles ($p \leq 0.05$) as compared to control, but the effect of chlorophenol and silver nanoparticles plus chlorophenol was not significant (Table 2). Mean comparisons showed that loss in fresh weight was least in 20 mg l^{-1} silver nanoparticles treatment (6.957 g) between silver nanoparticles treatments (Fig. 2). Additionally, 0 mM chlorophenol in combination with 20 mgl^{-1} silver nanoparticles (6.483 g) inhibited fresh weight loss more than control (16.01 g), but according to ANOVA, interaction of silver nanoparticles and chlorophenol were in significant (Table 2). It must have been due to changes in solution uptake in cut gerbera flowers. Hashemabadi (2012) reported that 15 mg l^{-1} silver nanoparticles was most effective treatment on the cut carnation (*Dianthus caryophyllus* 'Tempo') flowers, which delayed loss in fresh weight (3.38 g). It was due to the effect of silver nanoparticles on solution uptake enhancement and reduction of respiration. Lu *et al*. (2010) showed that silver nanoparticles treatment on cut rose (*Rosa hybrida* 'Movie Star') flowers caused water relation improvement, water stress control and finally, it prevented fresh weight loss. Along with suppression of microbial growth at stem ends, silver nanoparticles treatments tended to inhibit transpiration from leaves and suppress decrease in hydraulic conductance of cut stems. Liu *et al*. (2009) reported inhibitory effect of silver nanoparticles on fresh weight loss in cut gerbera (*Gerbera jamesonii* cv. 'Ruiko'). Similar to current findings, Basiri *et al*. (2011) showed that there was no significant effect between different silver nanoparticles concentrations and relative fresh weight of cut carnation flowers. Investigation of Liu *et al*. (2009) on the effect of silver nanoparticles on cut gerbera flowers revealed that silver nanoparticles pulsing delayed relative loss in fresh weight. 5 mgl^{-1} silver nanoparticles treatment maintained the relative fresh weight throughout the vase period. Solgi *et al*. (2009) demonstrated that all cut gerbera held in silver nanoparticles solutions showed significantly higher relative fresh weight than control. These researchers also showed that maximum relative fresh weight was obtained for cut flowers held in preservative solutions supplemented with 10 or 20 mgl^{-1} silver nitrate plus 4% sucrose.

According to the results, significant differences were found among various silver nanoparticles concentration ($p \leq 0.05$) and chlorophenol ($p \leq 0.01$) in extending the vase life of cut gerbera flowers. The longest vase life (16.33 days) was obtained with 20 mg l^{-1} silver nanoparticles plus 0 mM chlorophenol (Table 1). These findings are in close similarity to that of Liu *et al*. (2009) which demonstrated that all silver nanoparticles pulse treatments markedly extended cut gerbera vase life as compared to control. Current study revealed that 10 mM chlorophenol extended vase

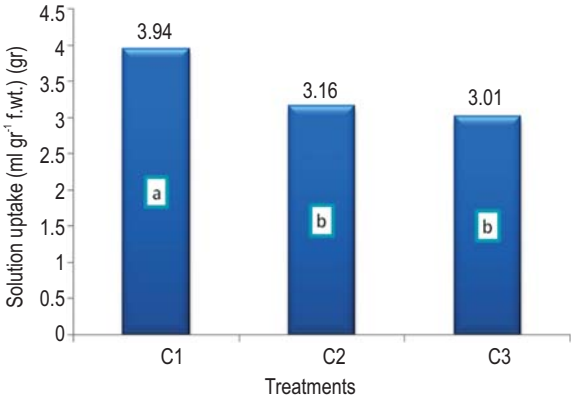

Fig 1 : Effect of silver nanoparticles and chlorophenol on solution uptake of *Gerbera jamesonii* cv. Balance

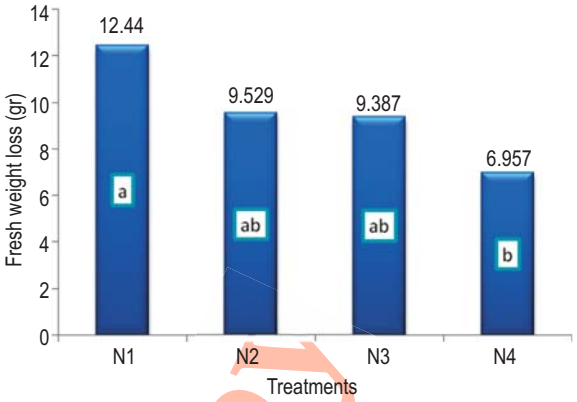

Fig 2 : Effect of silver nanoparticles and chlorophenol on fresh weight loss of *Gerbera jamesonii* cv. Balance

life higher than 5 mM, which is not in accordance with Serilong and Buanong (2007) on cut rose flowers. Mean comparison showed that the most effective treatment between chlorophenol levels was 0 mM, (it was found that, single effect of chlorophenol on vase life was negative), between silver nanoparticles concentration was 10 mg l^{-1}, and the longest vase life belonged 0 mM chlorophenol plus 10 mgl^{-1} silver nanoparticles which extended vase life about 2.33 days as compared to control (16.33 and 14 days, respectively) but as shown in Table 2, the interactive effect of silver nanoparticles and chlorophenol on vase life was in significant. Vase life was extended as silver nanoparticles level increased from 0 to 10 mg l^{-1}. Increasing the vase life of cut flowers was due to the effect of silver nanoparticles on enhancement in solution uptake and reduction in respiration (Basiri *et al*., 2011). The present results is in confirmation with earlier reports of (Kim *et al*. (2005), Liu *et al*. (2009) and Serilong and Buanong (2007), respectively. Mohammadi *et al*. (2011) studied silver nanoparticles treatments (0, 2.5, 5, 10 and 20 mg l^{-1}) on cut gladiolus (*Gladiolus grandiflora*) flowers and found that silver nanoparticles in all the above-mentioned concentrations could extend the vase life. Ansari *et al*. (2011) investigated the effect of silver nanoparticles, humic acid and gibberellic acid on cut gerbera cv. 'Good Timming' flowers and showed that 5 mg l^{-1} silver nanoparticles in combination with 4% sucrose and 2.5 mg l^{-1} gibberellic acid extended the vase life by about 1.8 days more than control. Liu *et al*. (2012) studied the effect of different concentrations and formulations of silver nanoparticles on cut *Acacia holoserica* flowers and found that 5 mg l^{-1} silver nanoparticles treatment was most effective concentration on the vase life of *Acacia*. Similar to this paper, Solgi *et al*. (2009) showed that addition of 5, 10 or 20 mg l^{-1} silver nitrate solution into preservative solution of cut gerbera flowers extended the vase life. The longest vase life was obtained with 10 mg l^{-1} silver nitrate solution. Flowers held in 5 or 10 mg l^{-1} silver nanoparticles had longer vase life than control (Solgi *et al*., 2009).

According to the results, significant differences were found among various concentrations of silver nanoparticles and chlorophenol ($p \leq 0.01$) on bacterial contamination of cut gerbera flowers (Table 2). Mean comparison among different concentrations of chlorophenol indicate that priority of 5 mM rather than control, and 5 mg l^{-1} silver nanoparticles was the best treatment between different silver nanoparticles levels (Table 1). Additionally, 5 mM chlorophenol plus 10 mg l^{-1} silver nanoparticles, and 10 mM chlorophenol plus 5 mg l^{-1} silver nanoparticles had unique effect with no contamination (Table 1). Effectiveness of chlorophenol was due to the inhibitory effect on polyphenoloxidase activity, an enzyme which induces stem blockage. These results are in accordance with Serilong and Buanong (2007) and Van Doorn and Nicolas (2002). Current study showed that bacterial colonies reduced from 27.55 to 0.22 $\log^{10}$ CFU ml^{-1} as silver nanoparticles level increased from 0 mg l^{-1} to 10 mg l^{-1}. Antibacterial effect of silver nanoparticles is due to their high surface to volume ratio, good contact with microorganisms and high interacts with cytoplasmic components and nucleic acids, inhibition of respiratory chain enzymes and interference with membrane permeability (Rai *et al*., 2009). Liu *et al*. (2009) studied the effect of silver nanoparticles on cut gerbera cv. Ruiko flowers and showed that the flowers treated with silver nanoparticles in different levels had less bacterial contamination than the control. Hashemabadi (2014) showed the inhibitory effect of 15 mg l^{-1} silver nanoparticles on bacterial contamination in cut carnation cv. 'Tempo' flowers. Liu *et al*. (2012) reported that silver nanoparticles enhanced solution uptake and inhibited bacterial growth in stem-end and finally delayed stem blockage. These findings confirm the findings of current results. silver nanoparticles have antibacterial effects (Sondi and Salopek-Sondi, 2004; Song *et al*., 2006) and can extend vase life of cut flowers (Solgi *et al*., 2009). Present studies showed efficacy of silver nanoparticles in extending the vase life and postharvest quality of cut gerbera (*Gerbera jamesonii* cv. 'Balance').

Results showed that silver nanoparticles and chlorophenol did not increase final day °Brix markedly, but

interaction of these treatments was significant ($p \leq 0.01$) on it. Mean comparison of data showed that 10 mM chlorophenol in combination with 5 mg l^{-1} silver nanoparticles was the best treatment, that increased final day °Brix up to 14.95%. Hashemabadi (2014) studied the effect of different concentrations of silver nanoparticles on cut carnation cv. 'Tempo' flowers and found that 5 mg l^{-1} silver nanoparticles was the most effective treatment on final day °Brix. Basiri *et al*. (2011) investigated the effect of different levels of silver nanoparticles on cut carnation cv. 'Yellow Liberty' flowers and found that these treatments enhanced final day °Brix. This result confirms the current finding and in accordance with the results of Mohammadi *et al*. (2011).

According to the findings, significant differences were found among various concentrations of silver nanoparticles and chlorophenol and their interactions ($p \leq 0.01$) on total protein content of cut gerbera petals (Table 2). Mean comparison among different concentrations of chlorophenol, silver nanoparticles and their interaction indicates priority of 5 mM chlorophenol (23.45%), 10 mgl^{-1} silver nanoparticles (23.2889%) and 5 Mm chlorophenol + 5 mg l^{-1} silver nanoparticles (29.4%) as compared to control. Vase life prolongation compound lessened endoprotease activity and delayed reduction of total protein content. Buchanan-Wollaston and Ainsworth (1997) revealed that along vase period and due to senescence, the main stored metabolites re-transferred into the plant system and protein refraction was the main part of this re-mobilization, so proteolytic enzymes activity was necessary factor of senescence. Halvey and Mayak (1979) reported that total protein content was reduced because of senescence. Wagstaff *et al*. (2002) revealed that endoprotease activity increased during the vase period in cut *Alestromeria* flowers. It was found that treatment with 2% sucrose prolonged vase life with interrupting endoprotease activity (Eason *et al*., 2002).

In conclusion, the current study showed that silver nanoparticles has antimicrobial property and delayed senescence in cut gerbera. The maximum vase life was observed in flowers held in solution containing 10 mg l^{-1} silver nanoparticles. The results revealed that silver nanoparticles and chlorophenol have potential of extending vase life and enhancing postharvest quality of cut gerbera cv. 'Balance' flowers.

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