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PAPER

DIP TREATMENTS FOR FRESH ROMAINE LETTUCE

TRATTAMENTI PER IMMERSIONE DI LATTUGA FRESCA ROMANA

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ABSTRACT

The effects of dip treatments with chlorine, citric acid, ascorbic acid and $CaCl_2$ on the storage life of Romaine lettuce leaves were investigated. While the presence of chlorine delayed degradation related to the activity of the native and exogenous microflora, the other compounds did not improve the storage life of the product when used alone. A combination of citric and ascorbic acid had a beneficial effect on the overall visual quality (color, texture, brightness). The ratio of ascorbic acid con-

RIASSUNTO

È stato studiato l'effetto del tratta
mento con cloro, acido citrico, acido
ascorbico e $CaCl_2$ sulla vita di scaffal
della lattuga Romana. Mentre la pre
senza di cloro è fondamentale per ri
tardare la degradazione collegata all'at
tività della flora nativa ed esogena, gl
altri additivi, quando applicati da soli
non hanno migliorato la vita di scaffal
del prodotto. La combinazione di acido
citrico e acido ascorbico ha avuto un
effetto vantaggioso sulle caratteristiche
organolettiche (colore, tessitura e lucen-

- Key words: disinfection, leafy vegetable quality, sensory attributes, storage -

ts in samples treated and not treat-
with ascorbic acid as additive was
ut 4.2:1 immediately after the dip
atment but dropped to about 2.1:1
r 10 days of storage.

tezza). Il rapporto tra il contenuto in acido ascorbico nei campioni trattati e non trattati con questi composti, è stato 4.2:1 immediatamente dopo il trattamento, ma è scesa a 2.1:1 dopo 10 giorni di conservazione.

INTRODUCTION

ttuce is a very perishable product,
emely sensitive to abuse such as
perature or mishandling. One of the
t common processing-induced dis-
rs is discoloration. Techniques that
ce surface and edge browning in-
e low storage temperatures (BOLIN
HUXSOLL, 1991), modified or con-
ed atmospheres with low oxygen (2%)
/or relatively high carbon dioxide
ls (7%) (KE and SALTVEIT, 1989a;
EOS *et al.*, 1993a,b; HEIMDAL *et al.*
5) and chemical additives (McEVILY
., 1992).

everal chemical compounds are re-
ed to have inhibitory effects on en-
atic browning of various commodi-
SAPERS *et al.* (1990) reduced dark-
g of "Russet Burbank" and "Katah-
potatoes by using a dip treatment
ascorbic acid, $CaCl_2$ and citric acid.
l_2 dips have been reported to delay
ning of pears and bananas (WILLS
TIRMAZI, 1982, POOVAIAH, 1986), re-
flesh softening (BANGERTH *et al.*,
2) and retain the vitamin C content
pple fruit (DRAKE and SPAYD, 1983).
treatments with ascorbic acid and
c acid alone have been shown to re-
enzymatic browning in freshly pre-
ed vegetables (BAUERNFEIND and
KERT, 1970; ANONYMOUS, 1983).
vever, PONTING *et al.* (1972) found
ascorbic acid or $CaCl_2$ alone did not
vent discoloration of refrigerated ap-
slices, but when used in a combina-
treatment they were very effective.
cium used alone or combined with other substances such as ascorbic acid or sulfur dioxide has been shown to maintain firmness of pear and strawberry slices (ROSEN and KADER, 1989), and carrot sticks (BRUEMMER, 1987).

Several authors have studied the quality of head and shredded iceberg lettuce as affected by processing conditions. Although iceberg is the predominant lettuce used for prepared salad, other types of lettuce are now used in salad mixes. Information on the postharvest behavior of these other types of lettuce is limited, especially with regard to their physiology and quality as a minimally processed product (LOPEZ-GALVEZ *et al.*, 1996). Lettuce quality is reduced and its shelf life shortened by tissue browning. Some of the most common post-harvest browning disorders of iceberg lettuce tissue are russet spotting (RS), brown stain (BS) (SALTVEIT, 1997), leaf surface browning (LSB), leaf edge browning (LEB) (LÓPEZ-GÁLVEZ *et al.*, 1996) and stem browning (SB).

BOLIN *et al.* (1977) stated that refrigeration temperature is used to extend the shelf life of shredded lettuce. Lettuce stored at 5° or 10°C had a statistically shorter shelf life (10 days) than samples held at 2°C (26 days) (BOLIN et al., 1977).

BOLIN and HUXSOLL (1991) found that dipping solutions of $CaCl_2$, citric acid or $ZnCl_2$ were ineffective in retaining the quality of salad-cut lettuce, but dipping in 0.5% ascorbic acid increased the shelf life by about 10%. KRAHN (1977) reported that sodium bisulfite and $CaCl_2$ were of little or no value in extending the shelf life of cut head lettuce. IZUMI and WATADA (1995) reported that the addition of chorine to a $CaCl_2$ dip enhanced the desirable effect of calcium on zucchini squash.

Taking into account that fresh horticultural crops differ in morphological structure, in composition and in general physiology, it is clear that requirements and recommendations for maximum post-harvest shelf life will differ. KE and SALTVEIT (1989b) and COUTURE *et al.* (1993) reported differences in the browning activities of various cultivars of lettuce when shredded and kept in different storage conditions.

The effectiveness of chemical dip treatments to increase post-harvest storage life is affected by pH, temperature, water activity, initial microbial load and storage atmosphere. Moreover, when different additives are used together they may cause either synergistic, additive or antagonistic effects (WILEY, 1997).

The purpose of the present work was to determine the response of whole Romaine lettuce leaves to various chemical treatments in order to extend its shelf life.

MATERIALS AND METHODS

Sample preparation

Heads of Romaine lettuce (*Lactuca sativa*, type Cos, variety Logifolia) were harvested at optimal maturity when they had reached a marketable size (approximately 20-24 leaves per head). They were immediately transported to the laboratory and analyzed by a sensory panel. Outer leaves were discarded and only photosynthetic leaves (green leaves) were included in the samples. Lettuce leaves were dipped in the various baths for 4 minutes at room temperature (ca. 20°C) at a weight ratio 1:10. The dipping baths were: 1) unchlorinated water (tap water with the following cation compositions: calcium 20 mg/L, magnesium 10 mg/L, sodium 250 mg/L, potassium 15 mg/
total iron 0.05 mg/L, manganese 0.
mg/L, and a water pH of 6.8-7.0); 2) chl
rinated water (Control). The source
chlorine was liquid sodium hypochlori
(NaOCl) and to achieve the best balan
of activity and stability of the hypochl
rous acid, the pH of the water was mai
tained between 6.5 and 7.5; 3) chlori
plus ascorbic acid (Chl-AA); 4) chlori
plus citric acid (Chl-CI); 5) chlorine pl
$CaCl_2$ (Chl-CA); 6) chlorine plus asco
bic acid plus citric acid (Chl-AA-CI);
chlorine plus ascorbic acid plus Ca
(Chl-AA-CA); 8) chlorine plus citric ac
plus $CaCl_2$ (Chl-CI-CA); 9) chlorine pl
ascorbic acid plus citric acid plus Ca
(Chl-AA-CI-CA). The chlorine concentra
tion was 0.1% sodium hypochlorite, t
ascorbic acid concentration was 0.5%
the citric acid concentration was 0.1
and the $CaCl_2$ concentration was 1%
the baths that included each of the
compounds. Lettuce leaves were r
moved from the baths without rinsi
and were centrifuged for 30 s at 200 rp
in a salad spinner to eliminate exce
solution adhering to the tissue surfac
Leaves were piled up in 100 g stack
placed in open plastic containers a
covered with a 15 m polyvinyl chlori
film, with an O_2 permeability of 62
2,248 $cm^3.m^{-2}.day^{-1}$ and a CO_2 perme
bility of 4,263-8,138 $cm^3.m^{-2}.day^{-1}$
atm-22°-25°C). Each container of 100
stacks corresponded to a duplicate
independent lots. These containers we
placed in holding boxes at a relative h
midity (RH) of 97-99% and a temper
ture of 4±1°C for 10 days. Beakers wi
saturated K_2SO_4 solutions were plac
in the boxes to maintain RH ca. 98%.

Microbiological studies

Lettuce leaves (25 g) were macerat
in PO_4H_2K buffer solution ($1.68x10^{-4}$
L adjusted to pH = 7.2 with 1 mol/
NaOH), with a homogenizer (Stomach
400 Circulator Homogenizer, Londo

K). The enumeration and differentia-
on of microorganisms were performed
sing the following culture media and
ulture conditions: mesophilic aerobic
cteria on PCA (Plate Count Agar) in-
bated at 35°C for 48 hours (ICMSF,
983; MOSSEL and MORENO GARCÍA,
985); psychrotrophic bacteria on PCA
cubated at 5°C for 3-4 days (ICMSF,
983); molds and yeasts in YGC (yeast-
ucose-chloramphenicol) medium and
cubated at 25°C for 5 days (ICMSF,
983). Microbial counts were performed
duplicate on three independent lots,
erefore count values are the mean of
x determinations.

Determination
of reduced ascorbic acid

Ascorbic acid content was determined
the titrimetric assay described by
LLETIER (1985). Ground lettuce (20
was torn manually by hand and add-
to 100 mL 6% metaphosphoric acid
d homogenized for 3 min, it was made
to 250 mL with 3% metaphosphoric
id and filtered through Whatman # 42
er paper. Aliquots (5 mL each) of the
trate were titrated with 2,6-dichloroin-
phenol. Ascorbic acid concentrations
g/100 g) are reported on a wet basis.
assays were performed in duplicate
three independent lots, therefore each
lue represents the mean of six deter-
nations.

Calcium content

The calcium concentration of samples
ated with $CaCl_2$ was calculated using
e method described by ROSEN and
DER (1989). Samples were filtered us-
g Whatman N. 12 filter paper and an-
zed on a Varian AA-375 Series Atom-
Absortion Spectrophotometer (Varian
chtron Pty. Ltd, Springuale, Austral-
and recorded on a dry-weight basis.
assays were performed in duplicate
three independent lots and each val-
ue represents the mean of six determi-
nations.

Sensory evaluation

Six judges, aged 30-45 years (4 fe-
males and 2 males, all members of the
UNMDP Food Engineering Research
Group), with sensory evaluation experi-
ence with leafy vegetables, were trained
in the quality evaluation of Romaine let-
tuce. At each sampling time (0, 2, 4, 6
and 10 days of storage), lettuce leaves
were removed from the plastic contain-
ers 20 min prior to evaluation to reach
room temperature. Lettuce leaves from
three independent lots were subjected to
sensory evaluation in duplicate. The cod-
ed (3 digit) samples were presented one
at a time in random order to the judges
who sat at around a table and made in-
dependent evaluations. Samples from
each treatment were evaluated for per-
centage and severity of injury and sub-
sequent decay. Evaluated indexes were
overall visual quality (OVQ: color, tex-
ture and brightness) (KADER *et al.*, 1973),
leaf surface browning (LSB) (LÓPEZ-
GÁLVEZ *et al.*, 1996), stem browning (SB)
and russet spotting (RS). OVQ was rat-
ed on a scale from 5 to 1, where 5 = ex-
cellent and 1 = unusable. An OVQ rat-
ing of 3 was considered the limit of sale-
ability. LSB, SB and RS were scored on
a scale from 1 to 5, where 1 = lack of
defects and 5 = severe defects. A score
of 3 was considered the limit for salea-
bility. For each of these defects, an in-
dex was calculated by multiplying the
scores by the percentage of pieces affect-
ed.

Statistical analysis

ANOVA was used to establish the lev-
els of significance of the differences
among the mean values from different
assays. Regression analysis was used to
draw least square lines representing the
degradation of sensory attributes over
time. Differences among slopes were test-
ed as indicated by VOLK (1958).

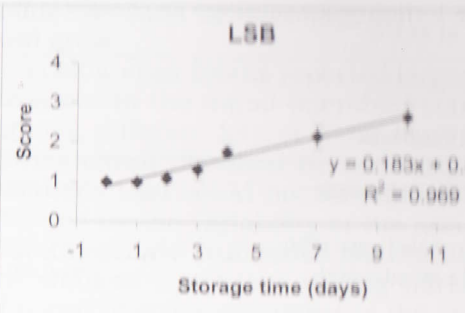
RESULTS AND DISCUSSION

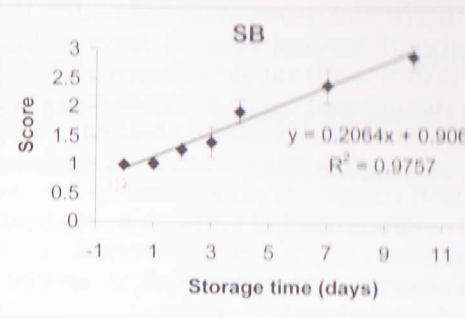
Sensory attributes

Scores for leaf superficial browning,
stem browning and overall visual quali-
ty of Romaine lettuce samples dipped in
chlorinated water over a 10-day storage
period at 4°C and 98% RH are present-
ed in Fig. 1. The regression equations
for the different quality parameters of the
samples from all the dip treatments are
reported in Table 1. Lower slopes repre-
sent lower rates of degradation. In com-
paring samples dipped in unchlorinated
and chlorinated water, there were high-
er rates of degradation for OVQ indexes
($p<0.01$) for the unchlorinated samples,
but there were no differences in the
slopes for the LSB and SB indexes. This
was due to the fact that, in the unchlo-
rinated samples, the native and exoge-
nous flora were still active and could
have caused necrosis and other delete-
rious effects (Fig. 2A). On the other hand,
the fact that chlorine did not affect the
development of LSB and SB indicates
that they reflect mostly enzymatic phe-
nomena and are not directly affected by
the presence of chlorine. The activity of
phenylalanine ammonia lyase is involved
in the phenylpropanoid pathway in phe-
nolic metabolism, leading to lettuce
browning (PEISER *et al.*, 1998).

The addition of ascorbic acid, citric
acid or $CaCl_2$ to the chlorine dipping so-
lution did not make any improvements
($P<0.10$) in the sensory indexes as com-
pared to lettuce treated with chlorinat-
ed water (control) (Table 1).

Samples treated with ascorbic acid
(Chl-AA) had higher slopes for OVQ, LSB
and SB ($P<0.10$) than with chlorine
alone. BOLIN and HUXSOLL (1991) re-
ported that 0.5% ascorbic acid increased
the shelf life of iceberg lettuce by 10%. A





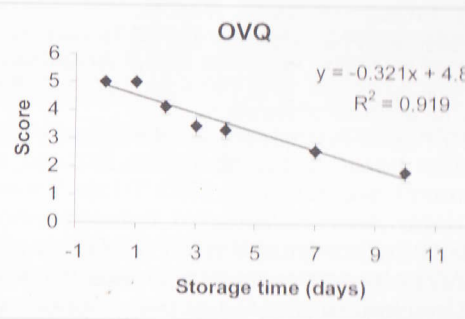


Fig. 1 - Evolution of LSB, SB and OVQ in lett
leaves dipped in water with 100 ppm of chlor
(Chlorinated water) during 10 days of storage
4°C. Means of six determinations. Vertical li
represent SD. Some SD bars are masked by
graph symbol.

possible explanation could be a diffe
ent response of the varieties (Iceberg a
Romaine) and the different storage co
ditions used.

Samples treated with chlorine and c
ric acid (Chl-Cl) had a faster decline
OVQ ($P<0.10$), than with chlorine alon
This is contradictory to the reports th
citric acid can benefit the storage life

e 1 - Regression equations for changes in the quality parameters (indexes) over 10 days of storage at 4±1°C.

? treatments	Quality parameters		
	OVQ	LSB	SB
chlorinated water	y=-0.461x + 4.808 b	y=0.249x + 0.700 n.s.	y=0.280x + 0.825 n.s.
lorinated water (Chl)	y=-0.321x + 4.859	y=0.183x + 0.870	y= 0.206x + 0.898
l + ascorbic acid	y=-0.491x + 4.925 b	y=0.293x + 0.792 b	y=0.358x + 0.776 b
l + citric acid	y=-0.441x + 4.601 b	y=0.235x + 0.878 n.s.	y=0.217x + 0.927 n.s.
l + $CaCl_2$	y=-0.326x + 4.509 n.s.	y=0.328x + 0.737 c	y=0.195x + 1.018 n.s.
l + ascorbic acid + citric acid	y=-0.232x + 4.995 a	y=0.170x + 1.003 n.s.	y=0.280x + 0.834 n.s.
l + ascorbic acid + $CaCl_2$	y=-0.414x + 4.881 b	y=0.160x + 0.887 n.s.	y=0.310x + 0.822 n.s.
l + citric acid + $CaCl_2$	y=-0.512x + 5.028 b	y=0.241x + 0.739 n.s.	y=0.142x + 0.988 n.s.
l + ascorbic acid + citric acid + $CaCl_2$	y=-0.262x + 4.431 a	y=0.412x + 0.898 c	y=0.326x + 0.844 n.s.

lope significantly lower than slope of dip treatment with chlorinated water (Chl) at P<0.10.
lope significantly higher than slope of dip treatment with chlorinated water (Chl) at P<0.10.
lope significantly higher than slope of dip treatment with chlorinated water (Chl) at P<0.05.
. No significant differences.
'Q = overall visual quality, LSB = leaf superficial browning, SB = stem browning.

uce by lowering the pH (BOLIN *et al.*, 77) or by preventing enzymatic brown- by chelation of Cu in polyphenol ox- se (WILEY, 1997).

Samples treated with chlorine and Cl_2 (Chl-CA) had a higher slope for LSB 0.05), with respect to chlorine alone. AHN (1977) also reported that the use $CaCl_2$ did not produce any benefits in ending the shelf life of cut head let- e. Also, the storage life of shredded uce (BOLIN *et al.*, 1977) was not ex- ded by calcium treatment. The lack response of lettuce to calcium com- red to other products such as apples, awberries, pears and carrots, may be to differences in its form, the con- ntration of the solution and storage nperature (IZUMI and WATADA, 1994). concentration of the remaining $CaCl_2$ on the lettuce was determined. After treatment, the concentration was 4 times higher (1,344 µg/g) than in non treated samples (330 µg/g). This concentration might be too high and produce negative effects on Romaine lettuce. SAMS *et al.* (1993), studying the effectiveness of post-harvest $CaCl_2$ treatments to maintain firmness and reduce decay of whole apples, found that excessive calcium could result in fruit injury.

The use of solutions containing a combination of two additives with chlorinated water produced mixed results. The simultaneous addition of citric and ascorbic acid (Chl-AA-Cl) produced a lower slope for the OVQ index ($p<0.10$) compared with lettuce treated with chlorinated water (control), without significantly affecting indexes that show enzymatic degradation such as LSB and SB. This could be due both to the lowering of the pH and to citric acid strengthening the action of ascorbic acid (WILEY, 1997).

The combination of ascorbic acid and $CaCl_2$ (Chl-AA-CA) and the combination of citric acid and $CaCl_2$ (Chl-CI-CA) produced greater declines in the OVQ index ($p<0.10$).

The simultaneous addition of ascorbic and citric acids and $CaCl_2$ (Chl-AA-CI-CA) gave beneficial effects on the OVQ index, but deleterious effects on the LSB index. Probably the presence of a high concentration of remaining calcium on the lettuce leaves after the $CaCl_2$ treatment, produced this negative effect.

Only the simultaneous addition of ascorbic and citric acids to chlorinated water (Chl-AA-CI) gave an improvement over chlorinated water alone (control).

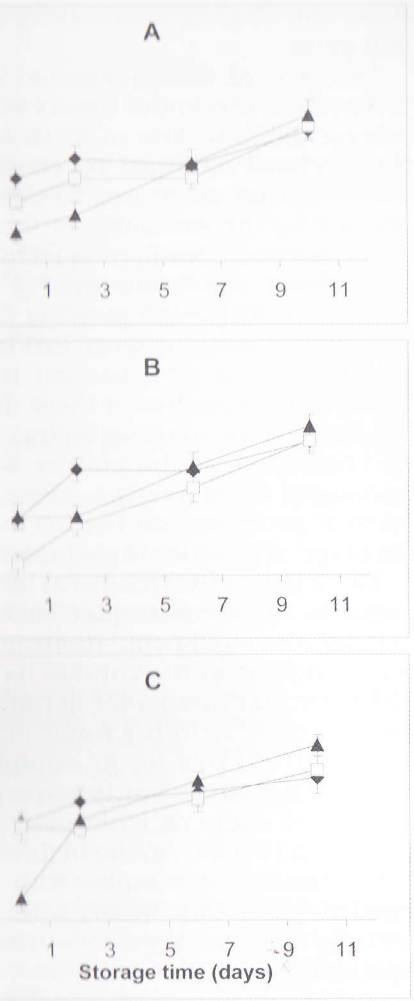
Russet spotting (RS) is a major physiological disorder of harvested Iceberg lettuce. It is induced by exposure to ethylene and is more severe at a temperature of 5°C (RITENOUR *et al.*, 1995). These authors indicated that when harvested Iceberg lettuce was exposed to 10 ppm of ethylene at 5°C, symptoms appeared after approximately 3 days of storage. In all the samples, the development of russet spotting showed no significant increase up to 6 days of storage. By day 10 of storage, the indexes increased slowly regardless of the bath treatment, reaching final values of 1.6 to 2.0.

Microbiological counts

A fundamental problem in extending the shelf life of minimally processed fruits and vegetables is microbial proliferation which must be retarded. Growth of disease-causing microorganisms is a food safety concern, especially with higher pH vegetables (in contrast to lower pH fruits). Visible growth and off-odors caused by microorganisms are aesthetically unacceptable. The ecological niche caused by the composition of the food will determine the kind of microorganisms t will grow.

PONCE *et al.* (2002) reported large ferences in the initial microbial cou among different lots of fresh leaves Swiss chard obtained by conventio methods that could not be entirely plained by the variability of the asse ment methods. Numerous factors, su as ambient conditions during harve amount of soil accompanying the pr uct, time elapsed between last irrigat and harvest or post-harvest handli could be responsible for these differe es. Since some of these factors can be controlled, initial counts would necessary whenever the effect of po harvest processes on the micro flora this type of product is evaluated.

Fig. 2 shows the trend of a) mesoph bacteria, b) psychrotrophic bacteria a c) yeast and mold populations on lettu leaves dipped in the various baths. I tial counts for mesophilic aerobic mic organisms were in the range of 1.3x1 to $2.5x10^6$ CFU/g for all sample tre ments. The initial counts correspondi to control samples (chlorinated wat were $7\text{-}8x10^5$ CFU/g, the highest cou corresponded to samples with unch rinated water (tap water) with 2-3x1 CFU/g and the lowest counts cor sponded to samples with chlorine pl ascorbic acid plus citric acid (Chl-AA- with $1\text{-}2x10^5$ CFU/g (Fig 2A). These sa ples maintained the lowest counts up 2 days of storage. Chlorine treatme reduced ($P<0.01$) the initial populati of natural contaminants. Hypochlori dips are commonly used in postharve practices for sanitizing fruits and veg tables, particularly in the fresh cut i dustry (BEHRSING *et al.*, 2000). Chlori acts on the microbial flora of vegetabl (WILEY, 1997; WATADA, 1997). Microbi activity has been shown to be associa ed with the development of necrosis du ing storage of lettuce leaves (NGUYE THE and PRUNIER, 1989; JACQUES a MORRIS, 1994). By 10 days no differen



Mean microbial Log_{10} counts of lettuce ing storage: Mesophilic bacteria (A), Psy- bacteria (B) and Yeasts and molds (C). rrespond to a mean of duplicates, ob- m three independent lots, therefore val- ie means of six determinations. Vertical esent SD. Some SD bars are masked by symbol.
orinated water treatment, □ - Chlorinat- reatment, ▲ - Chl-AA-CI.

01) in the populations of mes- aerobic microorganisms were n lettuce regardless of type of 5-8x10^7 CFU/g). For minimally ed vegetables, French legislation maximum of 5x10^7 CFU/g at the stage of consumption (BARRIGA *et al.*, 1991), hence the microbiological quality could be considered satisfactory during 10 days of storage.

The levels and trend of psychrotrophic microorganisms were similar to those of mesophilic aerobic microorganisms (Fig. 2B). The population increased from an initial level of 0.25-6x10^5 to 2-6x10^7 CFU/g. In general, the numbers of psychrotrophic microorganisms were acceptable. With the various chemical treatments investigated, no differences in the initial counts ($P<0.01$) were found. The lowest initial counts corresponded to the sample treated with chlorinated water.

The lowest initial counts for yeasts and molds (3-9x10^3 CFU/g) were for lettuce dipped in chlorine plus ascorbic acid (Chl-AA), chlorine plus ascorbic acid plus citric acid (Chl-AA-CI), chlorine plus ascorbic acid plus calcium (Chl-AA-CA), chlorine plus citric acid plus calcium (Chl-CI-CA) and chlorine plus ascorbic acid plus citric acid plus calcium (Chl-AA-CI-CA). This could probably be due to the low pH of these baths (pH 4-5). By day 10 of storage no differences ($p<0.01$) were found among dip treatments (Fig. 2C). BEUCHAT and GOLDEN (1989) studied antimicrobials that occur naturally in foods, and suggested that some organic acids can exert fungicidal and fungistatic action which is related directly to lowering the pH of the substrate.

The ability of both mesophilic and psychrotrophic bacteria and yeast and molds to multiply at the low temperatures assayed indicates their potential ability to cause lettuce spoilage.

Ascorbic acid contents

The initial ascorbic acid content of fresh leaf samples was 8.3 mg/100g of fresh weight. The endogenous ascorbic acid concentrations in the fresh lettuce used in this study were higher than those reported by ALBRECHT (1993) for Romaine lettuce. The ascorbic acid concentrations of samples dipped in treatments free of ascorbic acid were not significantly different ($P<0.05$). On the other hand samples treated with ascorbic acid had about a 4 times higher initial ascorbic acid content without significant differences among them. Fig. 3A presents the mean values obtained for the ascorbic acid concentration of samples treated without ascorbic acid (treatments with unchlorinated water, chlorinated water, Chl-CI, Chl-CA and Chl-CI-CA) and Fig. 3B presents the mean values obtained for the ascorbic acid concentration of samples treated with ascorbic acid (treatments with Chl-AA, Chl-AA-CI, Chl-AA-CA and Chl-AA-CI-CA). The difference between the means of both groups during storage was always significant ($p<0.01$).

The rate of ascorbic acid loss was lower in samples without ascorbic acid treatments than in samples with ascorbic acid treatments. For example, by day 4, samples without ascorbic acid had lost 50% of their initial ascorbic acid content, while samples with ascorbic acid had lost 77%. This difference could be attributed to the ascorbic acid being on the surface and more exposed to oxidation.

Nevertheless, in spite of the higher rates of ascorbic acid degradation in ascorbic acid-treated samples, their absolute concentrations remained higher than in the other samples during storage.

CONCLUSIONS

The effect of dip treatments with chlorine, $CaCl_2$, citric acid and ascorbic acid on the quality of Romaine lettuce leaves during storage was investigated. Chlorine may be required to inhibit the growth of bacteria responsible for necrosis. Neither citric acid nor ascorbic acid

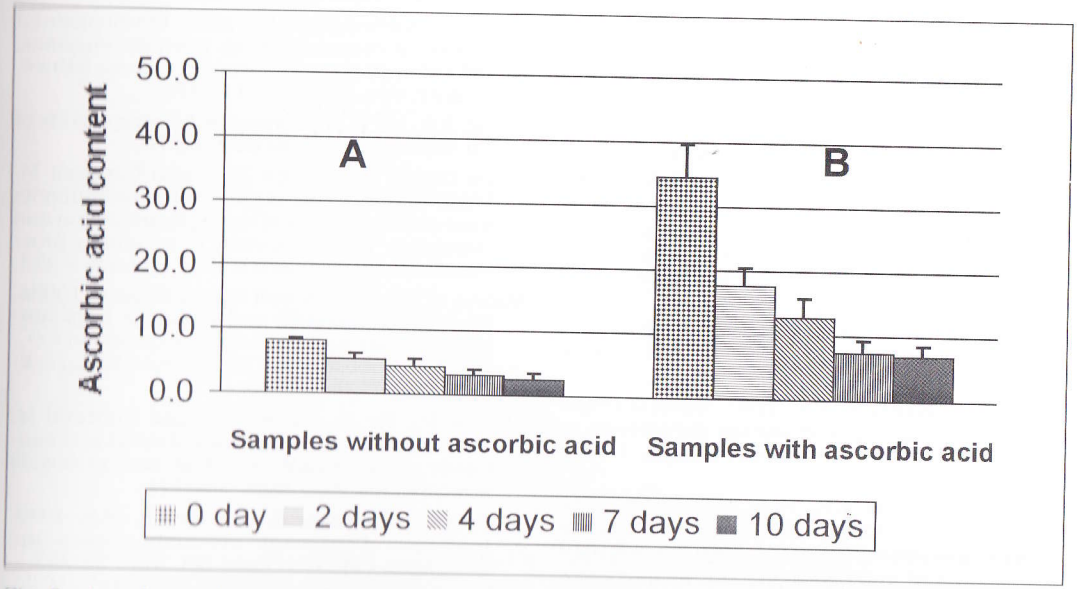


Fig. 3 - Ascorbic acid content (mg per 100g of fresh vegetable) in samples treated (A) without ascorbic acid (Chlorinated water, Unchlorinated water, Chl-CI, Chl-CA and Chl-CI-CA) and (B) samples treated with ascorbic acid (Chl-AA, Chl-AA-CI, Chl-AA-CA, Chl-AA-CI-CA) during 10 days of storage at 4°C. Means of six determinations. Vertical lines represent SD.

orinated solutions resulted in im-
ments in LSB, SB, OVQ indexes,
is in contrast with published re-
on Iceberg lettuce. However, the
nation of both acids resulted in a
decline of the overall visual qual-
the Romaine lettuce leaves. The
on of calcium chloride did not re-
improvements in the visual qual-
d could be responsible for faster
rface browning. Samples treated
ascorbic acid maintained higher
nts of ascorbic acid throughout
ge, although the rate of ascorbic
oss was higher than in samples not
l in ascorbic acid.

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