METHODS FOR INHIBITING THE DISCOLORATION OF PROCESSED BROCCOLI

A method for inhibiting the discoloration of processed fresh broccoli, comprising handling the broccoli for fresh consumption and exposing that processed fresh broccoli to a solution of sodium citrate, ascorbic acid, sodium acid pyrophosphate, and L-cysteine hydrochloride, in weight percentage ratios ranging from about 59.6 to about 72 parts sodium citrate, to about 14.4 to about 17.9 parts ascorbic acid, to about 12.6 to about 7.6 parts sodium acid pyrophosphate, and to about 6 to about 9.9 parts L-cysteine hydrochloride, and the remainder water until the sodium citrate, ascorbic acid, sodium acid pyrophosphate, and L-cysteine hydrochloride have been diluted to a combined weight percentage concentration of from about 0.25 to at least about 2.0 weight percent of the solution, the exposing including contacting the processed fresh broccoli with the solution for a time sufficient such that the contacting inhibits the discoloration of the processed fresh broccoli when the processed fresh broccoli is exposed to an atmosphere that would result in the discoloration of the processed fresh broccoli in the absence of the contacting.
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METHODS FOR INHIBITING THE DISCOLORATION
OF PROCESSED BROCCOLI

BACKGROUND OF THE INVENTION

This invention relates generally to methods for
inhibiting the discoloration of mechanically and
physiologically injured fruits and vegetables, and relates
more particularly to methods for inhibiting the discoloration
of minimally processed fresh broccoli.

When many fruits (i.e., apples, pears, peaches, avocados,
and bananas) and vegetables (i.e., beans, potatoes, mushrooms
and many root crops) are bruised, or are cut, peeled, or
processed in any other way that causes tissue injury, a black
or brown discoloration appears at the situs of the tissue
injury within a few minutes due to enzymes of the melanosis
reaction. This discoloration problem has been the subject of
much study, because of its obvious economic importance to the
food processing industry.

Of the estimated 3 billion pounds of broccoli that are
marketed in the United States each year, more than half are
processed soon after harvest and are shipped ready for
consumption. Whole, unprocessed heads of broccoli may be
stored under refrigeration for many weeks without significant
deterioration. However, processed fresh broccoli that has
been in refrigerated storage for just a week or two will
become pale green, the florets will begin to turn yellow, and
the cut stem will begin to brown. This latter form of
broccoli discoloration is referred to as cut stem
discoloration.

To date, the discoloration of processed fresh broccoli
has been controlled primarily by packing and shipping
broccoli in ice. Many broccoli processors and shippers place
processed fresh broccoli in water-resistant shipping boxes
and then cover the broccoli with ice. The costs of water-resistant boxes and ice, as well as the additional shipping weight added by the ice packaging, results in significant added costs for transporting broccoli from the field to market.

The rate at which the discoloration of processed fresh broccoli occurs is also a function of the physiological condition of the broccoli prior to harvesting and processing, the chemical treatments that are applied to the broccoli during processing, if any, and the humidity levels and the temperatures at which the processed fresh broccoli is stored. For example, variations in the physiology of the whole, unprocessed heads of broccoli caused by different degrees of environmental stress during the growing season, such as heat stress and drought stress, will result in variations in the onset of discoloration when the broccoli is processed, and stored under a given set of storage conditions. Broccoli that is grown in poorly irrigated fields tends to form discoloration more rapidly after processing than does broccoli that is grown in well irrigated fields, for example.

Discoloration is unsightly and unappetizing. As a result, consumers invariable associate discoloration with distastefully old broccoli, even though the taste and nutritional value of the processed fresh broccoli are not affected by the appearance of discoloration. Therefore, the appearance of discoloration leads to significant commercial waste if the processed fresh broccoli is pulled from the retail shelf before taste and nutrition are affected.
SUMMARY OF THE INVENTION

It is a principal objective of the present invention to provide new methods for treating harvested and processed fresh broccoli that effectively inhibit the onset of discoloration for a reasonably long period of time consistent with commercial requirements. The new methods of the present invention utilize safe and natural chemicals that are effective in such low concentrations that they do not impart an off-color or taste to the processed fresh broccoli to which they are applied.

One embodiment of the present invention is a method for inhibiting the discoloration of processed fresh broccoli, comprising handling the broccoli for fresh consumption and exposing that processed fresh broccoli to a solution of sodium citrate, ascorbic acid, sodium acid pyrophosphate, and L-cysteine hydrochloride, in weight percentage ratios ranging from about 59.6 to about 72 parts sodium citrate, to about 14.4 to about 17.9 parts ascorbic acid, to about 12.6 to about 7.6 parts sodium acid pyrophosphate, and to about 6 to about 9.9 parts L-cysteine hydrochloride, and the remainder water until the sodium citrate, ascorbic acid, sodium acid pyrophosphate, and L-cysteine hydrochloride have been diluted to a combined weight percentage concentration of from about 0.25 to at least about 2.0 weight percent of the solution, the exposing including contacting the processed fresh broccoli with the solution for a time sufficient such that the contacting inhibits the discoloration of the processed fresh broccoli when the processed fresh broccoli is exposed to an atmosphere that would result in the discoloration of the processed fresh broccoli in the absence of the contacting.

Another embodiment of the present invention is the method for inhibiting the discoloration of processed fresh broccoli set forth in the immediately preceding paragraph, and further comprising treating the processed fresh broccoli prior to, or
after, the exposing step with chlorinated water having a chlorine concentration of from about 50 ppm to less than about 150 ppm.

Related objects and advantages of the methods of the present invention will be evident from the following detailed description.
DESCRIPTION OF THE PREFERRED EMBODIMENT

For the purposes of promoting an understanding of the principles of the invention, reference will now be made to the preferred embodiments in the description and Examples that follow, and specific language will be used to describe the same. It will nevertheless be understood that no limitation of the scope of the invention is thereby intended, such alterations and further modifications in the illustrated embodiments, and such further applications of the principles of the invention as described therein being contemplated as would normally occur to one skilled in the art to which the invention relates.

The broccoli utilized in the following examples were acquired directly from broccoli processors in California within days of harvest. The broccoli was shipped from the California processors via overnight express in coolers packed with ice to a laboratory facility where the tests set forth in the following Examples were conducted.

Example 1

Processed fresh broccoli florets harvested by a central California processing plant were transported in ice to a California laboratory facility where the stems were trimmed and the florets were treated in the following manner 6 days after harvest.

A control group of the broccoli florets weighing approximately 5.0 pounds was selected. The control group was then bagged in a non-perforated, breathable film, and the bag was sealed and placed in refrigerated storage at about 36-40°F.

A formulation of about 72.0% by weight food grade sodium citrate, about 14.4% by weight ascorbic acid, about 7.6% by weight sodium acid pyrophosphate and about 6.0% by weight
L-cysteine hydrochloride was dissolved in 59°F tap water (10 ppm chlorine) to a final test solution concentration of about 1.0% by weight with a final pH of about 5.2. A test group of the same broccoli florets, also weighing approximately 5 pounds, was dipped for 1 minute in a 59°F tap water bath containing 50 ppm chlorine to approximate the treatment utilized by some California processing plants for processed fresh broccoli florets. The test group was then dipped in the chilled 1.0% by weight test solution for about 1 minute. The test group was then bagged in the same non-perforated film, and the bag was sealed and placed in refrigerated storage at about 36-40°F.

After 6 days, the control group and the test group were removed from storage and were examined for discoloration. The control group had a bad odor and the cut stems were very brown. The test group, by contrast, was still moist, had good color and taste, and had a sweet odor. The test group was returned to refrigerated storage, and was examined again after 14 days of refrigerated storage. Again, the test group was still moist, had good color and taste, and exhibited no cut stem discoloration.

**Example 2**

Processed fresh broccoli florets harvested by a central California processing plant were hydrocooled (water at < 37°F, 50 ppm Cl), bagged, and packed in ice by the processor. They were then transported to a California laboratory facility where they were held overnight at 38°F. The stems were trimmed and the florets were treated in the following manner the next day.

A control group of florets, weighing approximately 1.0 pound, was sprayed with 67°F tap water (10 ppm chlorine) for about 1.5 minutes and was then bagged in the processor's standard perforated CVP film and placed in refrigerated
storage at about 38°F.

A first formulation of about 72.0% by weight food grade sodium citrate, about 14.4% by weight ascorbic acid, about 7.6% by weight sodium acid pyrophosphate and about 6.0% by weight L-cysteine hydrochloride was diluted with 67°F tap water to a final first test solution concentration of about 2.0% by weight with a final pH of about 5.7. A 1.0 pound first test group of the same florets was then sprayed with the 2.0% by weight first test solution for about 1.5 minutes. The first test group was then bagged in the same type CVP film and placed in refrigerated storage at about 38°F.

A second formulation of about 59.6% by weight sodium citrate, about 17.9% by weight ascorbic acid, about 12.6% by weight sodium acid pyrophosphate and about 9.9% by weight L-cysteine hydrochloride was dissolved in 67°F tap water to a final second test solution concentration of about 1.2% by weight with a final pH of about 5.7. A 1.0 pound second test group of the same florets was then sprayed with the 1.2% by weight solution for about 1.5 minutes. The second test group was then packaged in the same type CVP film and placed in refrigerated storage at about 38°F.

For the first 17 days, the control group and test group florets were stored at about 38°F. The control group and test group florets were then transferred to storage at about 44°F, which is a more realistic storage temperature to replicate real market storage conditions.

After 11 additional days at about 44°F, the control group and the first and second test group florets were removed from storage and were examined for discoloration. The control group had begun to turn brown at the cut ends. The first and second test groups, by contrast, were still moist, had good color and taste, and exhibited no cut stem discoloration. The second test group was returned to refrigerated storage, and was examined again 3 days later. After 3 additional
days, the second test group was still moist, with good color and taste, and with no cut stem discoloration.

Example 3

Freshly harvested broccoli was processed by a central California processing plant, the fresh florets were packed in ice and were then transported to a California laboratory facility where the stems were trimmed and the florets were treated in the following manner 6 days after harvest.

A control group of the florets, weighing about 1 pound, was bagged in the processor's perforated film and placed in refrigerated storage at about 40°F.

A formulation of about 72.0% by weight food grade sodium citrate, about 14.4% by weight ascorbic acid, about 7.6% by weight sodium acid pyrophosphate and about 6.0% by weight L-cysteine hydrochloride was dissolved in tap water to a final test solution concentration of about 0.5% by weight with a final pH of about 5.9. A first test group of florets was dipped for about 1 minute in a 70°F tap water bath containing 50 ppm chlorine to approximate the present production treatment utilized by some California processing plants for processed fresh broccoli florets, and then was dipped for about 1 minute in the 0.5% by weight test solution at 70°F, and then placed in vented bags and stored at 40°F. A second test group of florets was dipped for about 1 minute in the 0.5% by weight test solution at 70°F, and then was dipped for about 1 minute in a 70°F water both containing 50 ppm chlorine (pH 5.9), and then placed in vented bags and stored at 40°F.

After 15 days, the control group had a bad odor and the cut stems were brown. The test groups were still moist, had good color and taste after 15 days, and even after 22 days. The best test group was the first group in which the florets
that had been dipped in a 70°F water solution containing 50 ppm chlorine before being treated with the 0.5% by weight test solution.

Example 4

5 Freshly harvested broccoli was processed by a central California processing plant, the fresh florets were hydrocooled (water at < 37°F, 150 ppm Cl), were packed in ice, and were then transported to a California laboratory facility where the stems were trimmed and the florets were treated in the following manner.

A control group of the florets, weighing about 1 pound, was bagged in standard, perforated CVP film, and was placed in storage at about 35°F.

A formulation of 72.0% by weight food grade sodium citrate, 14.4% by weight ascorbic acid, 7.6% by weight sodium acid pyrophosphate and 6.0% by weight L-cysteine hydrochloride was dissolved in 60°F tap water to a final test solution concentration of about 1.0% by weight with a final pH of about 5.5. A test group of florets was then sprayed with the 1.0% by weight test solution at a rate of about 4 ounces per pound of florets, and was then placed in the same standard, perforated CVP film, and was placed in storage at about 35°F.

After being in storage at about 35°F for 24 hours, the control and test groups were stored at about 40-42°F, which for the next 48 hour period was periodically raised to 50-60°F to mimic temperature fluctuations in the normal commercial broccoli distribution channels.

After 21 days of total storage, the control group had yellowed and the cut stems were brown. The test group was still green with no brown discoloration of the cut stems.
Example 5

Freshly harvested broccoli was processed by a central California processing plant, the fresh florets were hydrocooled (water at < 37°F, 50 ppm Cl ), were packed in ice, and were then transported to a California laboratory facility where the stems were trimmed and the florets were treated in the following manner.

A control group of the florets weighing approximately 22 pounds was placed in shallow boxes, covered with a plastic liner, and then placed in refrigerated storage at about 36°F.

A formulation of about 72.0% by weight food grade sodium citrate, about 14.4% by weight ascorbic acid, about 7.6% by weight sodium acid pyrophosphate and about 6.0% by weight L-cysteine hydrochloride was dissolved in 60°F tap water to a final test solution concentration of about 2.0% by weight with a final pH of about 5.2. A test group composed of 22 pounds of the same florets was then sprayed 4 times for 20 seconds each with the 2.0% by weight test solution. The test group was then placed in the same shallow boxes, covered with the same plastic liner, and placed in refrigerated storage at about 36°F.

After 28 days, the control group and the test group were examined for discoloration. The control group showed significant browning of the cut stems and loss of green color. The test group, by contrast, was still moist, had good color, and had no cut stem discoloration.

Example 6

Freshly harvested broccoli crowns were processed by a central California processing plant, were hydrocooled (water at < 37°F, 50 ppm Cl), were packed in ice, and were then transported to a California laboratory facility where the
stems were trimmed and the crowns were treated in the following manner.

A control group of the fresh crowns weighting approximately 20 pounds was placed in the processor's standard HV box, covered with non-perforated film, and placed in refrigerated storage at about 34°F.

A formulation of about 72.0% by weight food grade sodium citrate, about 14.4% by weight ascorbic acid, about 7.6% by weight sodium acid pyrophosphate, and about 6.0% by weight L-cysteine hydrochloride was dissolved in 60°F tap water to a final test solution concentration of about 1.0% by weight. A 20 pound test group of the crowns was then sprayed with one pint of the 1.0% by weight test solution. The test group was then placed in the same type HV box, covered with the same non-perforated film, and placed in refrigerated storage at about 34°F.

After 7 weeks, the control group and the test group were examined for discoloration. The control group had significant discoloration. The test group, by contrast, was still moist, had good color and taste, and was within commercially acceptable limits.

**Example 7**

Processed fresh broccoli florets harvested by a central California processing plant was hydrocooled (water at < 37°F, 50 ppm Cl), bagged, and packed in ice by the processor. They were then transported to a California laboratory facility where they were held overnight at 38°F. The next day, the stems were trimmed and the florets were treated in the following manner.

A control group of about 1 pound of florets was sprayed with 67°F tap water (10 ppm chlorine) for about 1.5 minutes, was then bagged in a breathable, non-perforated film, and was then placed in refrigerated storage at about 40°F.
A test solution of about 59.6% by weight food grade sodium citrate, about 17.9% by weight ascorbic acid, about 9.9% by weight sodium acid pyrophosphate and about 12.6% by weight L-cysteine hydrochloride was dissolved in tap water to a final solution concentration of about 1.2% by weight. A test group of about 1 pound of the same florets was then sprayed for about 1.5 minutes with the 1.2% by weight test solution. The test group was then bagged in the same film and placed in refrigerated storage at about 40°F.

After 21 days, the control group and the test group florets were removed from storage and were examined for discoloration. The control group had begun to turn brown at the cut stems and the florets were dull green. The test group, by contrast, was still moist, had good color, and exhibited no browning at the cut stems.

The solutions utilized in the methods of the present invention may be contacted with processed fresh broccoli crowns or florets in the conventional ways, such as by dipping, spraying or showering, including contacting the broccoli with the solutions in the conventional hydrocoolers utilized by broccoli processors, as set forth in the Examples, above. Spraying has been the preferred method in testing completed to date.

While the invention has been described in the Examples and descriptions, above, the same is to be considered as illustrative and not restrictive in character, it being understood that only the preferred embodiments have been described and that all changes and modifications that come within the spirit of the invention are desired to be protected. In work completed to date, for example, it has been noted that variations in broccoli physiology caused by different environmental stresses during the growing period,
such as different degrees of elevated heat stress and drought stress, will show higher levels of dehydration at different storage conditions, which may require slight modifications to the aqueous solutions utilized in the methods of the present invention to prevent the onset of discoloration. For example, broccoli that was grown in poorly irrigated fields tend to dehydrate more rapidly than broccoli that was grown in well irrigated fields.

Variations in the physiologies of broccoli crowns from different growing areas, and differences in the crown and drought stresses experienced by the broccoli as a whole prior to processing will require slight modifications in the methods set forth in the foregoing Examples to most efficiently inhibit the onset of discoloration. For example, in testing completed to date, formulations composed of about 72% by weight food grade sodium citrate, about 14.4% by weight ascorbic acid, about 7.6% weight sodium acid pyrophosphate, and about 6.0% by weight L-cysteine hydrochloride have been dissolved in tap water to a final concentration as low as about 0.25% by weight of the solution, have been chilled, and have been contacted with processed fresh broccoli florets in conventional ways, and have been effective in delaying the onset of discoloration of processed fresh broccoli that had not been severely stressed environmentally.
What is claimed is:

1. A method for inhibiting the discoloration of processed fresh broccoli, comprising handling the broccoli for fresh consumption and exposing that processed fresh broccoli to a solution of sodium citrate, ascorbic acid, sodium acid pyrophosphate, and L-cysteine hydrochloride, in weight percentage ratios ranging from about 59.6 to about 72 parts sodium citrate, to about 14.4 to about 17.9 parts ascorbic acid, to about 12.6 to about 7.6 parts sodium acid pyrophosphate, and to about 6 to about 9.9 parts L-cysteine hydrochloride, and the remainder water until the sodium citrate, ascorbic acid, sodium acid pyrophosphate, and L-cysteine hydrochloride have been diluted to a combined weight percentage concentration of from about 0.25 to at least about 2.0 weight percent of the solution, said exposing including contacting the processed fresh broccoli with the solution for a time sufficient such that said contacting inhibits the discoloration of the processed fresh broccoli when the processed fresh broccoli is exposed to an atmosphere that would result in the discoloration of the processed fresh broccoli in the absence of said contacting.

2. The method for inhibiting the discoloration of processed fresh broccoli of claim 1 wherein the solution of said exposing is of sodium citrate, ascorbic acid, sodium acid pyrophosphate, and L-cysteine hydrochloride in a weight percent ratio of about 72 parts sodium citrate, to about 14.4 parts ascorbic acid, to about 7.6 parts sodium acid pyrophosphate, to about 6 parts L-cysteine hydrochloride, and the remainder water until the sodium citrate, ascorbic acid, sodium acid pyrophosphate, and L-cysteine hydrochloride have been diluted to a combined weight percentage concentration of about 0.5 weight percent of the solution.
3. The method for inhibiting the discoloration of processed fresh broccoli of claim 1 wherein the solution of said exposing is of sodium citrate, ascorbic acid, sodium acid pyrophosphate, and L-cysteine hydrochloride in a weight percent ratio of about 72 parts sodium citrate, to about 14.4 parts ascorbic acid, to about 7.6 parts sodium acid pyrophosphate, to about 6 parts L-cysteine hydrochloride, and the remainder water until the sodium citrate, ascorbic acid, sodium acid pyrophosphate, and L-cysteine hydrochloride have been diluted to a combined weight percentage concentration of about 1.0 weight percent of the solution.

4. The method for inhibiting the discoloration of processed fresh broccoli of claim 1 wherein the solution of said exposing is of sodium citrate, ascorbic acid, sodium acid pyrophosphate, and L-cysteine hydrochloride in a weight percent ratio of about 72 parts sodium citrate, to about 14.4 parts ascorbic acid, to about 7.6 parts sodium acid pyrophosphate, to about 6 parts L-cysteine hydrochloride, and the remainder water until the sodium citrate, ascorbic acid, sodium acid pyrophosphate, and L-cysteine hydrochloride have been diluted to a combined weight percentage concentration of about 2.0 weight percent of the solution.

5. The method for inhibiting the discoloration of processed fresh broccoli of claim 1 wherein the solution of said exposing is of sodium citrate, ascorbic acid, sodium acid pyrophosphate, and L-cysteine hydrochloride in a weight percent ratio of about 59.6 parts sodium citrate, to about 17.9 parts ascorbic acid, to about 12.6 parts sodium acid pyrophosphate, to about 9.9 parts L-cysteine hydrochloride, and the remainder water until the sodium citrate, ascorbic acid, sodium acid pyrophosphate, and L-cysteine hydrochloride have been diluted to a combined weight percentage concentration of about 1.2 weight percent of the solution.
6. The method for inhibiting the discoloration of processed fresh broccoli of any one of claims 1 to 5 wherein the solution of said exposing is at a temperature of from about 60°F to about 70°F.

7. The method for inhibiting the discoloration of processed fresh broccoli of claim 6, and further comprising treating said processed fresh broccoli prior to said exposing with chlorinated water having a chlorine concentration of from about 50 ppm to less than about 150 ppm.

8. The method for inhibiting the discoloration of processed fresh broccoli of claim 6, and further comprising treating said processed fresh broccoli after said exposing with chlorinated water having a chlorine concentration of from about 50 ppm to less than about 150 ppm.
INTERNATIONAL SEARCH REPORT

INTERNATIONAL APPLICATION NO.
PCT/US95/13046

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) : A23B 7/10, 7/154; A23L 3/00, 3/34
US CL : 426/262, 268, 321
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 426/262, 268, 321

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

APS

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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* Further documents are listed in the continuation of Box C. * See patent family annex.

Date of the actual completion of the international search
02 JANUARY 1996

Date of mailing of the international search report
21 FEB 1996

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