

Effect of Processing and Packaging Conditions on Quality of Refrigerated Potato Strips

M.E. Oner and P.N. Walker

Abstract: Although sulfiting agents are commonly used in the fresh-cut potato industry, concerns about further regulatory restrictions on sulfite use and consumer fear of sulfite-treated foods have lead to increased research in alternative processing methods. The objective of this study was to determine processing and packaging techniques to achieve a safe and high-quality potato strips with a 4 wk minimum refrigerated shelf life. Potato strips were 1st blanched at low temperature (60 °C) in 0.5% CaCl₂ solution for 20 min and then 2nd blanched at high temperature (approximately 98 °C) in water for 5 min. Blanched strips were packaged in a near-aseptic environment or treated in-package with gaseous ozone, sodium metabisulfite (SM) solution, or FIT Fruit and Vegetable Wash™ (Procter and Gamble Co., Cincinnati, Ohio, U.S.A.) and then stored at 7 ± 1 °C for 28 d. No significant difference was observed in lightness of near-aseptically packaged fries, FIT-treated fries, and frozen fries; however, less color difference was determined in near-aseptically packaged fries and FIT-treated fries compared to frozen fries. Gaseous ozone treatment decreased color quality of potato strips, significantly. The highest after-frying peak force was observed in FIT-treated strips. There was no significant difference in oil absorption of refrigerated and unprocessed strips. These results indicate that either near-aseptic packaging or in-package FIT treatment are the better alternatives for blanched potato strips to extend shelf life and maintain quality.

Keywords: color, in-package, near-aseptic, shelf life, texture

Practical Application: In this study, several processing conditions and packaging methods were evaluated to improve quality and extend shelf life of refrigerated potato strips. Results indicate that the combination of 2-step blanching and near-aseptic packaging was an effective nonchemical processing method, giving 28 d refrigerated shelf life. Similarly, FIT Fruit and Vegetable Wash™ proved to be an effective chemical alternative to sulfites and avoids the allergen concern.

Introduction

Sulfiting agents such as sodium metabisulfite (SM) are preferred in preservation of food products in the industry due to their antimicrobial action (DiPersio and others 2003), ability to prevent enzymatic and nonenzymatic browning (Marshall and others 2000), and low cost. However, there are some regulatory restrictions on usage of sulfites preventing use in meats, other foods recognized as a source of thiamine, and fruits and vegetables that are consumed fresh, due to adverse affects on human health (FDA 1994). Thus, researchers have focused on finding alternative chemicals but none of them are as effective as sulfites (Gunes and Lee 1997; Laurila and others 1998). Although sulfites are allowed to use for fresh potatoes, since they are cooked before consumption (Petri and others 2008), alternative processing methods are needed due to concerns about future federal restrictions on sulfite usage.

Ozone is a highly reactive generally recognized as safe (GRAS) status (FDA 2001) antimicrobial with a lack of residual effect or chemical residue. Gaseous ozone treatments are generally more effective than aqueous ozone treatments. Bialka and Demirci (2007) were able to reduce *Salmonella* and *Escherichia coli* O157:H7 on

strawberries by 2.60 and 2.96 log₁₀ CFU/g, respectively, using gaseous treatments. No significant changes observed in color after ozone treatments. Klockow and Keener (2009) analyzed the effectiveness of “in-package” gaseous ozone treatment on spinach leaves. They were able to reduce *E. coli* O157:H7 in spinach by 3 to 5 log₁₀ CFU/leaf after 24-h storage.

FIT Fruit and Vegetable Wash™ (Procter and Gamble Co., Cincinnati, Ohio, U.S.A.) is marketed as an effective antimicrobial. It consists of GRAS status substances levulinic acid (FDA 2004) (21 CFR 172.515) and sodium dodecyl sulfate (SDS) (FDA 1978) (21 CFR 172.822). Zhao and others (2009) were able to reduce both *Salmonella* and *E. coli* O157:H7 populations on lettuce greater than 6.7 log₁₀ CFU/g by using 3% levulinic acid and 1% SDS for less than 20 s.

Hot water surface pasteurization is an effective sanitizing method. Immersion in hot water reduces microbial population by providing excellent heat transfer through the food surface (Pao and Davis 1999; Annous and others 2004). Beside the microbial effects, hot water treatment improves general quality. Two-step water blanching improves the textural and color quality of potato strips. Low-temperature blanch (50 to 70 °C) improves texture by activating pectin methylesterase enzyme (Andersson and others 1994; Nourian and Ramaswamy 2003; Ni and others 2005) and a following high-temperature blanch (for example, boiling water) improves color by inactivating phenolase enzyme (Canet and Hill 1987; Agblor and Scanlon 2000). The addition of calcium chloride into blanching water enhances the firmness (Jaswal 1970)

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and the whitening (Severini and others 2003) of the potato strips.

Hot water treatment improves quality and reduces microbial load. However, it is not sufficient to extend shelf life unless produce is packaged in an environment free of spoilage microorganisms. Either treating blanched potato strips with chemicals inside the package or packaging in pasteurized environment (near-aseptic packaging) might be useful methods to improve shelf life. The objective of this study was to determine the effect of near-aseptic packaging and in-package chemical treatments on shelf life of blanched potato strips based on microbial, color and textural qualities, and oil content.

Materials and Methods

Preparation and blanching of potato strips

Potatoes (Russet Burbank variety) were provided by Sterman Masser, Inc. (Sacramento, Pa., U.S.A.) and stored at 13 to 14 °C until used. Potatoes were washed and cut into 11 × 11 × 50 mm (approximately 7.5 ± 0.4 g) strips with a manual potato cutter. Only strips with minimal or no skin were used. Potato strips were held in potable water (approximately 20 °C) during preparation to minimize browning. Approximately 300 potato strips were 1st blanched at 60 °C for 20 min in 0.5% CaCl₂ solution and then kept in potable water (approximately 20 °C) until 2nd blanching. Four weeks later 20 unprocessed potato strips (freshly cut strips without blanching and/or chemical treatment) were prepared from the same batch of potato tubers using the same method as for the blanched product. Potato tubers were cut into strips just before quality (texture and color) analysis in order to prevent quality degradation.

Near-aseptic packaging of blanched potato strips

The glove-box packaging chamber (interior dimensions: 60 × 94 × 122 cm), with the packaging bags suspended inside, was

sealed and heated by filling with steam at atmospheric pressure for 30 min after steam flow was observed exiting the chamber (Figure 1). The air filter was similarly and simultaneously pasteurized. After pasteurization, the steam was gradually replaced with filtered air and then the chamber was further cooled by recirculating water, cooled to 4 °C by a refrigeration system, through the heat exchanger located inside the chamber. During steam heating, cool-down and operation, a minimal but continuous positive pressure was maintained inside the chamber as indicated by inflation of the gloves.

After preparation of the near-aseptic packaging system, potato strips 1st blanched at low temperature were placed into the product blanching column (height × diameter: 32.5 × 7.9 cm) for 2nd blanching in recirculating boiling water (approximately 98 °C) provided from a kettle (187 L, Model D9MT, Lee Industries Inc., Philipsburg, Pa., U.S.A.). After 2nd blanching in product column, potato strips were discharged from bottom of column into the chamber where they were drained and air-cooled for approximately 10 min. Twenty potato strips were packaged into each bag (liter-size Ziploc freezer bag, S.C. Johnson Co., Racine, Wis., U.S.A.). The bags remained inside the chamber until all samples were made and then were removed from the chamber by disassembling a chamber wall. Three bags of near-aseptically packaged potato strips were used as that treatment. Other identically prepared bags of strips produced at the same time were used to manufacture the in-package chemical treatment samples.

Recontamination of blanched potato strips before in-package chemical treatments

Approximately 60 near-aseptic potato strips were taken from the bags and placed on a sieve, arranged in a single layer, and held for 30 min in order to allow surface contamination from laboratory atmosphere. After recontamination, 20 strips were placed into each bag and were used for each treatment with chemicals as described

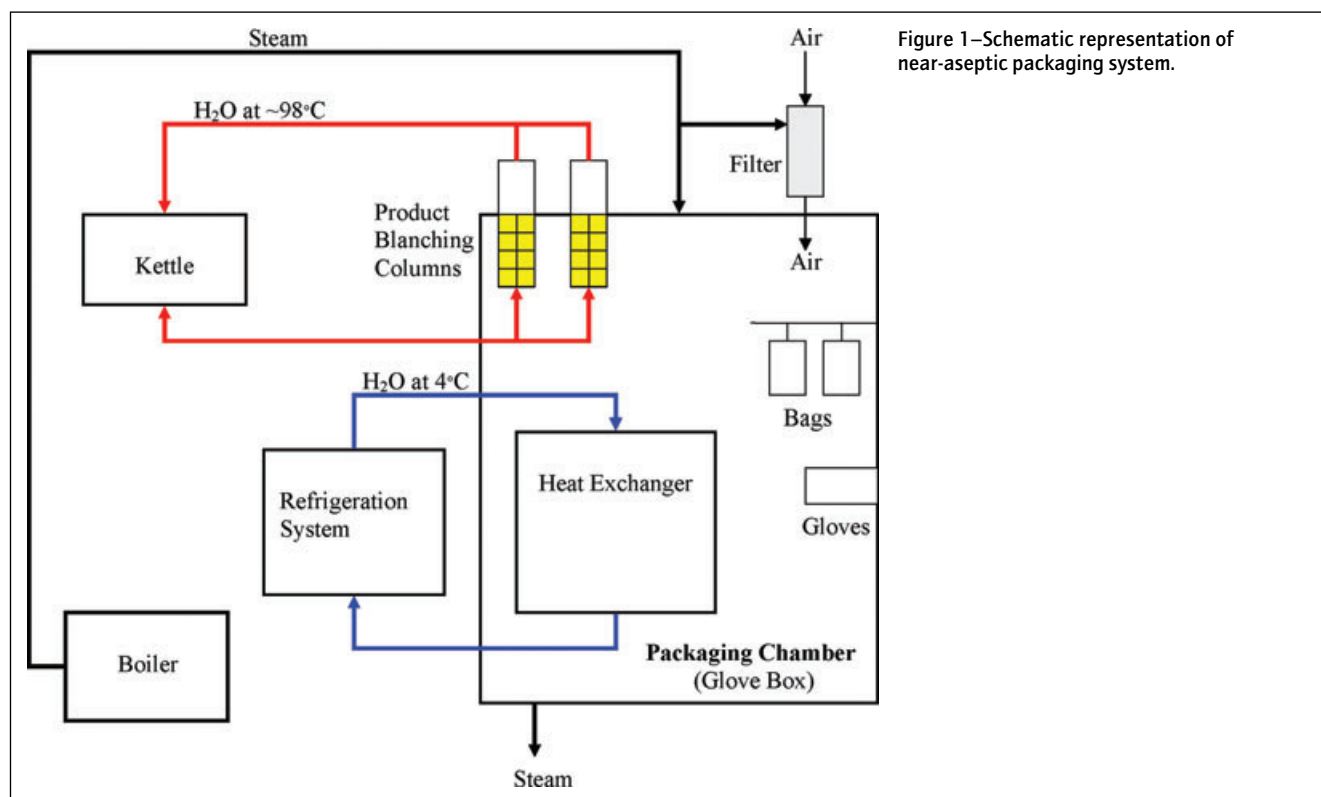


Figure 1—Schematic representation of near-aseptic packaging system.

in below. Three bags with contaminated strips were also kept as a control.

Ozone treatment of blanched potato strips

Bags with 20 blanched and contaminated strips were vacuumed and heat sealed by using a vacuum packaging machine (Model MV45, Minipack-torre S.P.A, Dalmine, Italy) and 2 septa were attached to each bag scheduled to receive an ozone treatment. Continuous ozone gas (5% wt/wt) with a flow rate of 0.34 m³/h (Bialka and Demirci 2007) was injected into each vacuumed bag for 30 min with a needle connected to the ozone generator and inserted through one of the septum. A 2nd needle and septum provided an exit and allowed for a continuous flow through the bag. The septa minimized leakage of gas in or out of the bag after treatment.

A laboratory scale ozone generator (Model H-50, Hess Machines Intl., Ephrata, Pa., U.S.A.) equipped with an oxygen concentrator was used for ozone treatment. Ozone concentration in the gas stream was measured before treatments with a Teledyne 450H bench-top analyzer (Teledyne Technologies, Inc., Los Angeles, Calif., U.S.A.). The exhaust ozone gas was passed through a 2% (wt/vol) potassium iodide aqueous solution to prevent ozone from being released into the environment. All ozone treatments were performed in a fume hood for safety considerations.

SM and FIT treatments of blanched potato strips

Twenty blanched and recontaminated potato strips were treated with 0.7 L of SM solution (9 g/L) or FIT Fruit and Vegetable WashTM solution (diluted to achieve pH 3) inside the bag for 1 min. One chemical solution was poured into each Ziploc bag containing the strips along with a volume of air approximately twice the volume of solution and sealed by using the zipper closure. The bag was turned over once each 2nd during the treatment. After treatment, the solution was drained by holding the bag inverted with a zipper side at a 45° angle with the horizontal and the slider positioned at the lower corner of the bag. The slider was opened a small amount to allow the solution to slowly drain, while allowing no air to enter and was closed just before the surface of the solution reached the opening. Treated potato strips were stored at 7 ± 1 °C for 4 wk.

Refrigerated storage

Three bags each for near-aseptically packaged and ozone, SM, and FIT in-package treatments were stored for 4 wk at 7 ± 1 °C in a refrigerator (Kenmore 60722, Ill., U.S.A.) with its thermostat custom modified to allow higher than normal set points. Recommended refrigeration storage temperature varies between 0 and 4.4 °C (USDA 2010). The higher 7 °C temperature was chosen to partially account for temperature abuse during storage and thereby provide more conservative results.

Microbiological analysis

Mesophilic bacteria, psychrotrophic bacteria, and yeast-mold populations were determined after the 28 d of storage. Three potato strips (approximately 25 g) were homogenized with a stomacher for 2.5 min in sterile stomacher filter bags containing 225 mL 0.1% sterile peptone water (Difco, Detroit, Mich., U.S.A.). Mesophilic and psychrotrophic bacteria were enumerated by spiral plating (Autoplate 4000, Spiral Biotech, Norwood, Mass., U.S.A.) method using plate count agar (PCA) and incubating plates at 30 ± 1 °C for 48 h and 7 ± 1 °C for 10 d,

respectively. Yeast-mold counts were performed in potato dextrose agar by incubating at 25 ± 1 °C for 5 d. All samples were analyzed in duplicate. Colonies were counted by using an auto-counter (Q-Count, Version 2.1, Spiral Biotech) after incubation and results were expressed as CFU/g of potato tissue.

To ensure detection of low levels of microbial growth, samples were enriched. An enrichment protocol was performed by transferring 1 mL the stomaching solution to 9 mL of trypticase soy broth (TSB) for mesophiles and potato dextrose broth (PDB) for mold and yeast (Difco, Detroit). After incubating at 30 °C for 2 d, growth in the enrichments was determined visually.

Texture, color, and oil-content analyses

Texture, color, and oil content analyses were applied to near-aseptically packaged potato strips, in-package ozone-, SM-, and FIT-treated strips after 28 d of storage at 7 ± 1 °C. Unprocessed samples and commercial frozen potato fries (9.5 × 9.5 mm Ore-Ida Golden Fries, H.J. Heinz Co., Pittsburgh, Pa., U.S.A.) were also analyzed. Texture and color quality of potato strips were compared before and after frying.

To determine after-frying quality, 10 potato strips were fried in 2.5 L of corn oil, heated to an initial temperature of 177 °C for 4 min using an electric fry cooker (Model 0692001, 1500 W, Presto, Eau Claire, Wis., U.S.A.) controlled by an external temperature controller (Digi-Sense model 89000-10, Cole Parmer, Vernon Hills, Ill., U.S.A.). Because of differences in processing and storage conditions of refrigerated and frozen potato strips, frozen potato strips were fried at 190 °C for 7 min as recommended on their bag. Potato fries were held at room conditions for 3 and 5 min before beginning color and texture measurements, respectively.

An Instron model 4444 Universal Testing machine (Instron, Norwood, Mass., U.S.A.) was used to analyze texture of potato strips. A plate with a 3-mm hole was attached to the machine. A potato strip was placed onto the plate and a 2-mm probe moved downward through the strip at a rate of 0.42 mm/s. The peak force required to puncture the top surface of the potato strip was used to determine textural quality. Each potato strip was measured at 3 locations, 2 ends, and a center. A total of 15 data were obtained from 5 potato strips.

A Konica Minolta Chroma Meter CR-400 (Konica Minolta, Ramsey, N.J., U.S.A.) was used to define color of potato strips by measuring $L^*a^*b^*$ color space. In this color space, L^* is the lightness that ranges from 0 to 100, and chromatic components of a^* (from green to red) and b^* (from blue to yellow) range from -60 to 60. ΔE^* indicates the total color difference that is calculated with Eq. (1) (Konica Minolta 1998; Nourian and Ramaswamy 2003). That color difference is between the processed potato sample and the reference values from the white plate provided by the manufacturer.

$$\Delta E^* = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2} \quad (1)$$

Prior to use, Chroma Meter was calibrated against a standard white plate. During measurements, potato strips were placed snugly side-by-side in a single layer on a tray and the CIE $L^*a^*b^*$ values were recorded 20 times from 5 strips by measuring 2 different locations on each strip. Color analysis was applied before and after frying. In after-frying measurements, potato fries were held under room conditions for 3 min before measurement.

Oil content was determined by Soxhlet extraction method using a Goldfish Fat Extractor apparatus (Labconco Corp., Kansas City,

Mo., U.S.A.). Four potato strips from each treatment were dried in an oven at 105 °C for 2 d and then ground into small particles. A porous cellulose thimble containing a 2-g sample and a beaker containing ethyl ether were placed in the extraction chamber. The beaker was heated and the ether evaporated up into the condenser. The evaporated ether was condensed into a liquid that drained through and leached the oil from the sample and then drained back to the beaker. Ether refluxed through thimble for 16 to 18 h. After extraction, the ether was evaporated from the beaker, leaving the oil. The weight of the oil was measured and the percentage of oil in the initial sample was calculated as in Eq. (2).

$$\% \text{Oil content} = \frac{\text{Weight of extracted oil}}{\text{Weight of dried sample}} \times 100 \quad (2)$$

Statistical analysis

All experiments were replicated 3 times and MINITAB statistical software (version15, MINITAB Inc, State College, Pa., U.S.A.) was used to analyze differences between treatments. Analysis of variance at a 95% confidence level and Tukey's least significance difference test were used to determine significant differences between treatments.

Results and Discussion

Microbiological quality of potato strips

Mesophilic bacteria, psychrotrophic bacteria, and mold-yeast populations were analyzed for treated potato strips after 28 d of storage at 7 ± 1 °C. Plate counts revealed no microbial growth in potato strips either near-aseptically packaged or in-package treated with gaseous ozone, SM solution, or FIT wash. Enrichment protocols confirmed the results. Microbial spoilage was detected visually in the control samples after 7 d of storage, confirming that the recontamination process used before in-package treatments was successful.

Table 1—Peak force (N) of potato strips for 6 different processes after 28 d of storage at 7 ± 1 °C.

Processes	Before frying	After frying
Unprocessed ²	8.23 ± 0.28 a ¹	1.34 ± 0.19 a
Near-aseptic packaging ³	5.36 ± 0.23 bc	2.92 ± 0.18 b
Sodium metabisulfite ³	5.45 ± 0.38 bc	2.89 ± 0.12 b
Ozone ³	5.07 ± 0.13 b	3.11 ± 0.31 b
FIT ³	5.94 ± 0.39 c	3.84 ± 0.22 c
Frozen ⁴		2.13 ± 0.24 d

¹Within the same column, values not followed by the same letter are significantly different ($P < 0.05$).

²Freshly cut strips without blanching and/or chemical treatment.

³Processed potato strips were stored at 7 ± 1 °C for 28 d.

⁴Commercial frozen potato fries (9.5 × 9.5 mm Ore-Ida Golden Fries, H.J. Heinz Co.).

Table 2— L^* and ΔE values of potato strips for 6 different processes.

Processes	Before frying		After frying	
	L^*	ΔE	L^*	ΔE
Unprocessed ²	70.38 ± 0.30 a ¹	29.99 ± 0.31 ab	52.33 ± 1.02 a	56.54 ± 2.26 a
Near-aseptic packaging ³	65.64 ± 0.12 bc	32.15 ± 0.16 b	61.32 ± 0.24 b	43.31 ± 0.28 b
Sodium metabisulfite ³	67.85 ± 1.52 ce	30.13 ± 1.44 ab	65.93 ± 0.70 c	36.51 ± 0.73 c
Ozone ³	61.83 ± 1.43 d	36.46 ± 1.51 c	40.58 ± 0.73 d	64.99 ± 0.77 d
FIT ³	69.83 ± 0.43 ae	28.03 ± 0.44 a	60.25 ± 0.33 b	44.05 ± 0.67 b
Frozen ⁴	65.32 ± 0.60 b	40.64 ± 0.33 d	59.80 ± 0.93 b	52.37 ± 1.74 e

¹Within the same column, values not followed by the same letter are significantly different ($P < 0.05$).

²Freshly cut strips without blanching and/or chemical treatment.

³Processed potato strips were stored at 7 ± 1 °C for 28 d.

⁴Commercial frozen potato fries (9.5 × 9.5 mm Ore-Ida Golden Fries, H.J. Heinz Co.).

Textural quality of potato strips

Textural quality results are listed in Table 1. Higher peak force ($P < 0.05$) was determined in unprocessed potato strips when measured before frying. Lower peak forces were determined in blanched strips because the high-temperature blanching treatment, effectively a cooking treatment, weakens the cell wall of the strips (Djomdi and Ndjouenkeu 2007), and causes texture degradation. There was no significant difference between before-frying textural qualities of near-aseptically packaged, SM-, and ozone-treated strips. Average values of before-frying peak force for ozone-treated strips were lower compared to near-aseptically packaged strips ($P > 0.05$), SM-treated strips ($P > 0.05$), and FIT-treated strips ($P < 0.05$).

When after-frying textural quality was compared, the lowest peak force ($P < 0.05$) was determined in the unprocessed fries. No significant difference was observed in after-frying textural quality of fries that were near-aseptic packaged, SM-, and ozone-treated. Higher peak force ($P < 0.05$) was determined in FIT-treated fries. Peak force for frozen potato fries was higher ($P < 0.05$) than unprocessed fries and lower ($P < 0.05$) than fries processed as near-aseptically packaged, SM-, FIT-, and ozone-treated fries. In frozen potato fries, processing conditions such as blanching, drying, addition of surface coatings, and partial frying can cause differences in crust formation compared to other treatments.

Color quality of potato strips

Lightness (L^*) and total color difference (ΔE) values of potato strips for the 6 different processes are listed in Table 2. Higher L^* value and lower ΔE values are interpreted as lighter color and less color difference, respectively. There was no significant difference in before-frying L^* and ΔE^* values of FIT-treated strips compared to unprocessed strips. Likewise, FIT-treated strips were not significantly different than SM-treated strips. However, FIT-treated strips were better ($P < 0.05$) in before-frying color than near-aseptically packaged strips and ozone-treated strips. The nominal 3.0 pH of the FIT solution can be effective at inactivation of phenolase because irreversible inactivation of phenolase can be achieved below 3.0 pH (Richardson and Hyslop 1985). SM inhibits enzymatic browning (Marshall and others 2000) and this is consistent with the higher L^* and lower ΔE color values that were determined in before-frying SM-treated strips compared to near-aseptically packaged potato strips even though the difference was not significant. Lower L^* and higher ΔE values were determined in before- and after-frying of ozone-treated strips compared to other treatments. Although potato strips were 2-step blanched, phenolase enzyme may not have been completely inactivated. Since ozone decomposes quickly (Guzel-Seydim and others 2004), oxygen level increases inside the package and may cause browning. Beltran and others (2005) found significant increase in

browning for ozone-treated modified atmosphere packaged potato strips.

The appearance of potato fries from the 6 different treatment processes is shown in Figure 2, illustrating the differences that are shown numerically in Table 2. SM-treated potato fries were lighter in color ($P < 0.05$) compared to other treatments and less color difference ($P < 0.05$) was also observed in SM-treated fries because sulfiting agents inhibit both enzymatic and nonenzymatic browning (Marshall and others 2000). No significant difference was determined in after-frying L^* values of near-aseptically packaged fries, FIT-treated fries, and frozen fries. However, total color difference was higher ($P < 0.05$) compared to near-aseptically packaged fries and FIT-treated fries.

Oil content of potato strips

The oil content data for the prepared potato fries are shown in Table 3. Frozen potato fries were higher ($P < 0.05$) in oil content compared to the other treated potato fries and unprocessed potato fries. No significant difference was observed in oil content of untreated, near-aseptically packaged, SM-, ozone-, and FIT-treated fries. Aguilar and others (1997) reported that low temperature (55 to 70 °C) and long-time blanching (15 to 60 min) of

potato strips decreased the oil content compared to unblanched strips. Although near-aseptically packaged, SM-, ozone-, and FIT-treated strips were blanched at low temperature (60 °C) for 20 min, here only insignificantly higher oil content was found in the unprocessed fries compared to 2-step blanched potato fries. This was most likely due to the subsequent 5 min high-temperature blanching (approximately 98 °C) that causes weakening of cellular structure in the strips.

Table 3–Oil content of potato fries processed in 6 different conditions.

Processes	Oil content (% d.b.)
Unprocessed ²	8.838 ± 0.432 a ¹
Near-aseptic packaging ³	7.946 ± 1.152 a
Sodium metabisulfite ³	8.133 ± 2.275 a
Ozone ³	8.213 ± 1.276 a
FIT ³	8.087 ± 0.222 a
Frozen ⁴	21.602 ± 2.340 b

¹ Within the same column, values not followed by the same letter are significantly different ($P < 0.05$).
² Freshly cut strips without blanching and/or chemical treatment.
³ Processed potato strips were stored at 7 ± 1 °C for 28 d.
⁴ Commercial frozen potato fries (9.5 × 9.5 mm Ore-Ida Golden Fries, H.J. Heinz Co.).

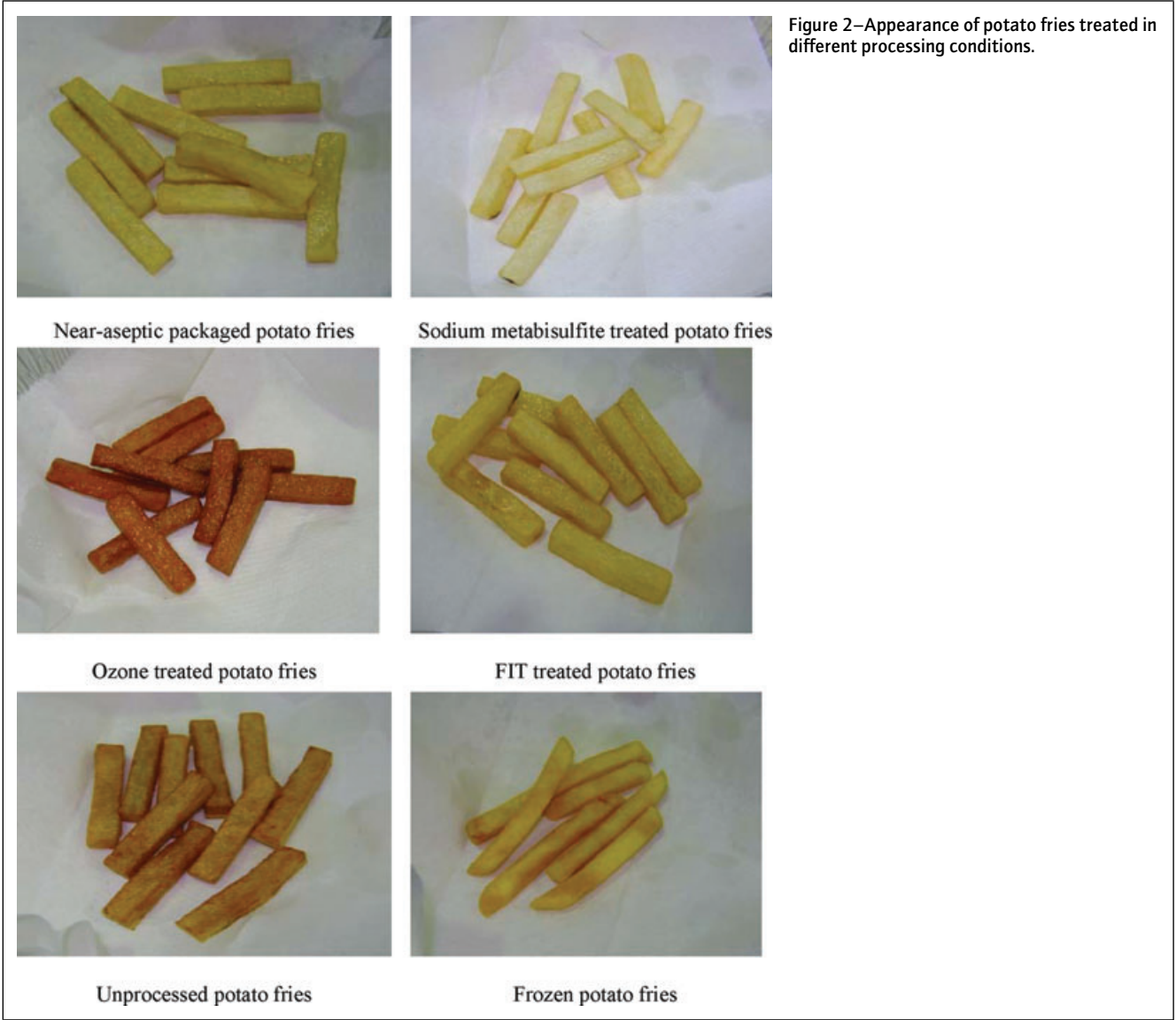


Figure 2–Appearance of potato fries treated in different processing conditions.

Conclusions

Two-step blanching is necessary in refrigerated potato strips processing for after-frying color and textural quality. Either near-aseptic packaging or in-package chemical treatment extended the shelf life up to 28 d at 7 ± 1 °C without microbial growth. SM increased the lightness of strips before and after frying. No significant difference was observed in color quality of near-aseptically packaged and FIT-treated fries. FIT treatment increased the after-frying peak force of fries. Gaseous ozone treatment decreased the color quality, significantly. Results indicate that the combination of 2-step blanching and near-aseptic packaging was an effective nonchemical processing method to extend shelf life and maintain quality under refrigerated storage. Similarly, FIT wash proved to be an effective chemical alternative to SM and avoids the allergen concern.

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