Storage stability of dried tomato slices during storage as affected by salt and lemon pretreatments

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ABSTRACT
The effects of salt pretreated with different concentration of lemon juice were investigated in order to improve the storage stability of dried tomato slices during six months storage. After six months of storage under controlled conditions, the results revealed that the moisture, color parameters (lightness, L*; redness, a* and yellowing, b*) and total phenolic of the sliced dried tomatoes pretreated with lemocta Technologica Agriculturae juice (6% and 8%) showed a non-significant difference (p > .05) during storage compared to the control dried tomato slices. Lycopene and β-carotene levels in lemon juice pretreated dried tomato slices (6% and 8%) decreased less than in untreated dried tomato slices during storage. The pretreatments with specific mixtures with salt (15%) and lemon juice (6% and 8%) are the pretreatments that best preserve the color and bioactive molecules of the sliced dried tomato during storage. These pretreatments can be used by processors when drying the tomato for better preservation of the nutritional components of the tomato.

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Introduction
Tomato (Lycopersicum esculentum Mill.) is a ubiquitous vegetable widely consumed in the world and play an important role in the population diets in West Africa and particularly in Burkina Faso. It is daily used in the preparation of several dishes in fresh or processed forms. In addition, tomato constitute a main raw material for a number of foods processing companies that provide to consumers a range of variety of processed products. Nutritionally, the tomato is an important source of nutrients and nutraceutical including carotenoids (β-carotene, lycopene), total phenolic, vitamins (C, B1, B2, B3, B6, B9, K) and minerals (iron, potassium, phosphorus, magnesium, sodium). Epidemiological studies have shown that the consumption of tomatoes and tomato products can protect the body’s cells against stress, the effects of aging and certain chronic diseases. It may reduce the risk of cancer of the liver, prostate, breast, colon and lungs, diabetes, cardiovascular disease and osteoporosis. Tomato production in many countries is seasonal and characterized by a short period of overproduction followed by a long period of scarcity. In times of overproduction, significant postharvest losses are reported due to limited control of postharvest operations and lack of appropriate processing technologies. In Africa, the scarcity of supply during the lean season led to import of fresh tomatoes from neighboring countries as well as tomato concentrates, mainly from Italy, China, and Singapore. Postharvest processing such as drying prevent post-harvest losses and ensures product availability at
affordable cost. However, the dried tomato is challenged with problems of organoleptic, nutritional and sanitary quality, thus limit its marketing. Drying methods were reported to have effects on the derived products.\textsuperscript{[11]} Indeed, dried tomato slice does not meet generally the quality standards and consumer expectations. In addition, during processing and storage, it undergoes alterations leading to a modification of the organoleptic (color, taste, texture, aroma) and nutritional quality of these derived products\textsuperscript{[12,13]} indicating that process variables, such as type of dryer, drying conditions, sample pretreatment and edible coating, are expected to impact the color and surface of dried products.

According to previous studies,\textsuperscript{[4,11,14–16]} control of the drying process such as pretreatment, drying temperature allow upgrading the quality of dried tomato. Indeed, salt and lemon, which are preservatives can be used as a pretreatment to improve the quality of dried tomatoes. The objective of the present study was then to improve the nutritional and organoleptic quality of dried tomato slices during storage by investigating the effects of different salt and lemon pretreatment method.

**Material and methods**

**Raw material**

Tomato fruits of Mongal F1 variety, red, were purchased from the local market of Ouagadougou (Burkina Faso). The collected tomato fruits were sorted and 30 kg were washed in water bath, surface sterilized with 0.24\% sodium hypochlorite for 10 min and then rinsed with distilled water.

**Pre-drying treatments**

The washed tomatoes were then sliced. The sliced fruits were divided into four groups of 5 kg: a first group control (C) was not submitted to pretreatment; A second group was soaked in a solution containing 15\% salt and 4\% lemon (L4) for 5 min and then drained. The third group was soaked in a solution of 15\% salt and 6\% lemon (L6) for 5 min and then drained. The fourth group was soaked in a solution containing 15\% NaCl and 8\% lemon (L8) for 5 min, and then drained (Figure 1).

**Drying processes**

For drying, the control, and the other three groups were dried in a cabin gas dryer at a temperature of 50 to 60°C for 12 h. After drying, the dried tomato slices were packaged in aluminum bags and stored at room temperature (29 ± 02°C) until required for analyzes. The drying operations were carried out in duplicate. Each month, during the storage period (6 months), duplicate samples from the same pretreatment were taken for analyses. The level of salt, lemon juice and soaking time were chosen according to the previous studies\textsuperscript{[14,15]} as mentioned in Table 1.

**Instrumental color values (L*, a*, b*)**

The color parameter values of different tomato samples were determined using a colorimeter (PCE-CSM 1, PCE instruments, I’m Langel 4, D-59872 Meschede, Deutschland) based on the color system of the International Commission on Illumination (CIELAB): L*, a*, b* and C*, h. The parameters lightness (L *), redness (a *) and yellowness (b *) were measured in triplicates for each sample by placing the objective of the colorimeter on a homogeneous surface of the products. The values of the parameters C*, a*/b*, h*, were calculated as follows:

\[
(\text{Chroma C}) = \sqrt{a^{*2} + b^{*2}}
\]  

(1)

The C * index represents the saturation of the color.
Hue $\theta$ = tan$^{-1}\left(\frac{b}{a}\right)$ \hspace{1cm} (2)

Where, the tint angle or tonality ($\theta$), redness to yellowness ration ($a*/b*$), is the color ratio which essentially indicates the darkening of the product.

**Moisture, ash, total acidity, pH**

The moisture and ash contents was determined according to AOAC$^\text{[17]}$. The results were expressed as percentage (%). The acidity and the pH were determined according to AOAC$^\text{[18]}$. 

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**Figure 1.** Pictures of control and pretreated dried tomato slices during storage.C: Control: tomato pulp without any treatment; L4: cut tomato pulp pretreated with 15% NaCl and 4% lemon juice; L6: tomato pulp pretreated with 15% NaCl and 6% lemon; L8: tomato pulp pretreated with 15% NaCl and 8% lemon (L8). FT, fresh tomato. All pretreatments were performed for 5 min.

| Pretreatments          | Specific conditions                                    | Code |
|------------------------|--------------------------------------------------------|------|
| Control                | 0% salt + 0% lemon juice                               | C    |
| Salt + lemon soak      | 15% salt + 4% lemon juice, 5 min                       | L4   |
|                        | 15% salt + 6% lemon juice, 5 min                       | L6   |
|                        | 15% salt + 8% lemon juice, 5 min                       | L8   |
| Production date        | 22/11/2018                                             |      |
| Analyzed Parameters    | Moisture content, ash content, pH, titratable acidity, total soluble solids, total phenolic, β-carotene, lycopene |      |
| Analysis of samples    | immediately after drying (t0), 1 month (t1), 2 months (t2), 3 months (t3), 4 months (t4), 6 months (t5) |      |

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Table 1. Pre-drying treatments.
**β-carotene and Lycopene**

The β-carotene and lycopene contents were determined by high performance liquid chromatography (HPLC, AGILENT 1100, Germany), as described by Somé et al.\(^{[19]}\) For the preparation of standard curve, 0.15 mg of β-carotene or lycopene (standard, Sigma BCVV2933) was dissolved in 3 ml of hexane. Dilutions 1/10, 1/100, 1/1000 of this solution were made. The optical densities (OD) were read at 450 nm. The sample solutions whose OD were between 0.1 and 0.9 were chosen. Their concentration was then calculated according to the formula:

\[
C = \frac{OD}{e_{\lambda}} \times 10^{-3} \, \text{μgml}^{-1}
\]

where “OD” is the optical density and \(e_{\lambda}\) is the molar extinction coefficient at 450 nm. OD is the optical density read and \(e_{\lambda}\) is the molar extinction coefficient. For the extraction, a sample (1 g) of paste was put in a tube. The β-carotene and lycopene were extracted by vortexing with 2 × 2 ml of hexane in the presence of echinenone (internal standard) at a concentration of 0.6 pmol µl\(^{-1}\). After vigorous stirring, the mixture was centrifuged at 3000 rpm, at −5°C, for 5 min. The supernatants were combined and evaporated under a stream of nitrogen. The resulting residue was combined with 800 µl of acetonitrile containing 15 pmol/20 µl of the internal standard. After filtration, the sample was injected in the HPLC column (Kinetex Phenomenex) using a loop of 20 µl. After injection of the calibration mixture, of defined concentration, and including the internal standard, for each peak, a relative calibration factor was calculated.

**Total phenolic**

Total phenolic content of the tomato extract was determined by spectrophotometry according to the Folin-Ciocalteu method\(^{[20]}\) with slight modifications. For extraction, 1% (V/V) HCl-methanol- was used for extraction. Tomato pulp (5 g) was mixed with 100 ml of the solvent and homogenized for 10 min then transferred to conical flask. The ground samples were extracted using the maceration technique by soaking the samples in the solvents, 4°C for 24 h; followed by filtration using Whatman No. 1 paper. The filtered extract was used to determine the total phenolic content. For the assay, 0.250 ml of each sample was introduced into test tubes and mixed with 1.25 ml of a 2 N Folin-Ciocalteu reagent. After 5 min of incubation, 1 ml of 7.5% sodium carbonate was added to generate the phenolate ions. The tubes were covered with aluminum foil and placed in a water bath at 65°C for 20 min before the absorbance was read at 760 nm using spectrophotometer. The samples were prepared in triplicate for each analysis. The results were expressed in mg of gallic acid equivalent (GAE) per 100 g of dry matter.

**Statistical analysis**

All experiments were performed in triplicate. The data were submitted for analysis of variance (ANOVA) using the XLSTAT software (Ver.2014.5.03). Duncan’s multiple range test was used to separate means. Significance was accepted at \(p \leq 0.05\).

**Results and discussion**

**Moisture contents, total ash, pH and total acidity**

Moisture contents, total ash, pH, and total acidity of dried tomato slices are significantly different at the onset of the experimentation and during storage (Table 2). At t0, the moisture content was between 15.88 ± 0.70% for the dried tomato slices pretreated with lemon at 4% (C4) and 19.33 ± 0.53% for the control dried tomatoes slices (C). During storage (t0 to t6), the water content of the dried tomatoes slices L6 and L8 were stable while for the dried tomato slices C and L4 an increase of 6.52% and 2.39%, respectively was observed. The fresh tomato (FT) had a high water content of 94.18% ± 0.12. According to the CEE-ONU Standard,\(^{[21]}\) dried tomatoes with a water
Table 2. Moisture, total ash content, pH and total acidity of dried tomato slices not pretreated and pretreated during storage.

| Parameters                  | Time of storage | Signification |
|-----------------------------|-----------------|---------------|
|                             | t0 (0 months)   | t1 (01 months)| t2 (02 months)| t3 (03 months)| t4 (04 months)| t6 (06 months)|          |
| Moisture content (%)        | C               | L4            | L6            | L8            | FT            |               |          |
|                             | 19.33 ± 0.53<sup>c</sup> | 15.88 ± 0.70<sup>a</sup> | 16.91 ± 0.23<sup>ab</sup> | 16.62 ± 0.45<sup>ab</sup> | 94.18 ± 0.12<sup>a</sup> |               |          |
|                             | 20.26 ± 0.41<sup>cd</sup> | 16.15 ± 0.29<sup>ab</sup> | 16.79 ± 1.02<sup>ab</sup> | 16.77 ± 0.63<sup>ab</sup> |               |               |          |
|                             | 20.26 ± 0.64<sup>cd</sup> | 16.57 ± 0.68<sup>ab</sup> | 16.74 ± 0.13<sup>ab</sup> | 16.60 ± 0.44<sup>ab</sup> |               |               |          |
|                             | 20.46 ± 0.68<sup>cd</sup> | 17.02 ± 0.14<sup>ab</sup> | 16.82 ± 0.75<sup>ab</sup> | 16.70 ± 0.10<sup>ab</sup> |               |               |          |
|                             | 20.23 ± 0.18<sup>cd</sup> | 17.52 ± 0.26<sup>ab</sup> | 15.93 ± 0.46<sup>b</sup>  | 16.74 ± 0.35<sup>ab</sup> |               |               |          |
|                             | 20.59 ± 2.80<sup>cd</sup> | 16.26 ± 0.40<sup>b</sup>  | 16.51 ± 1.27<sup>b</sup>  | 16.79 ± 0.30<sup>b</sup>  |               |               |          |
| Ash content (%)             | C               | L4            | L6            | L8            | FT            |               |          |
|                             | 11.03 ± 2.65<sup>cd</sup> | 29.31 ± 0.10<sup>ab</sup> | 26.42 ± 2.47<sup>ab</sup> | 28.09 ± 2.50<sup>a</sup> | 997 ± 0.13<sup>a</sup> |               |          |
|                             | 11.74 ± 0.26<sup>cd</sup> | 29.51 ± 0.09<sup>ab</sup> | 28.38 ± 0.36<sup>ab</sup> | 29.04 ± 0.71<sup>a</sup> |               |               |          |
|                             | 10.51 ± 1.41<sup>cd</sup> | 29.76 ± 0.06<sup>ab</sup> | 27.95 ± 0.01<sup>ab</sup> | 28.54 ± 0.22<sup>a</sup> |               |               |          |
|                             | 11.49 ± 3.00<sup>cd</sup> | 29.13 ± 0.20<sup>ab</sup> | 27.11 ± 0.16<sup>ab</sup> | 28.81 ± 1.13<sup>a</sup> |               |               |          |
|                             | 9.24 ± 4.91<sup>b</sup>  | 28.85 ± 0.16<sup>ab</sup> | 28.05 ± 0.01<sup>a</sup>  | 28.19 ± 0.15 |               |               |          |
|                             | 10.11 ± 3.47<sup>bc</sup> | 27.11 ± 0.27<sup>ab</sup> | 27.74 ± 0.65<sup>b</sup>  | 27.87 ± 0.47<sup>ab</sup> |               |               |          |
| pH                          | C               | L4            | L6            | L8            | FT            |               |          |
|                             | 4.19 ± 0.01<sup>b</sup>  | 4.02 ± 0.01<sup>ab</sup> | 4.04 ± 0.01<sup>bc</sup> | 4.03 ± 0.02<sup>b</sup> | 4.17 ± 0.00<sup>b</sup> |               |          |
|                             | 4.14 ± 0.00<sup>n</sup>  | 3.99 ± 0.00<sup>bc</sup> | 4.02 ± 0.01<sup>ad</sup> | 4.03 ± 0.01<sup>c</sup> |               |               |          |
|                             | 4.12 ± 0.00<sup>m</sup>  | 4.00 ± 0.01<sup>bc</sup> | 4.03 ± 0.01<sup>ae</sup> | 4.03 ± 0.01<sup>d</sup> |               |               |          |
|                             | 4.00 ± 0.00<sup>bc</sup> | 3.87 ± 0.00<sup>cd</sup> | 3.89 ± 0.00<sup>cde</sup> | 3.89 ± 0.00<sup>d</sup> |               |               |          |
| Total acidity (% citric acid equivalent) | C | L4 | L6 | L8 | FT |
|                             | 9.03 ± 0.57<sup>d</sup> | 7.02 ± 0.06<sup>b</sup> | 7.01 ± 0.51<sup>bc</sup> | 7.15 ± 0.15<sup>b</sup> | 0.48 ± 0.1<sup>b</sup> |               |          |
|                             | 9.41 ± 0.12<sup>e</sup> | 7.14 ± 0.09<sup>b</sup> | 7.17 ± 0.10<sup>b</sup> | 7.14 ± 0.09<sup>b</sup> |               |               |          |
|                             | 9.52 ± 0.21<sup>e</sup> | 7.56 ± 0.06<sup>c</sup> | 7.20 ± 0.03<sup>b</sup> | 7.14 ± 0.11<sup>b</sup> |               |               |          |
|                             | 9.62 ± 0.02<sup>f</sup> | 7.72 ± 0.12<sup>c</sup> | 7.20 ± 0.33<sup>b</sup> | 7.12 ± 0.09<sup>b</sup> |               |               |          |
|                             | 9.90 ± 0.03<sup>g</sup> | 7.55 ± 0.08<sup>e</sup> | 7.19 ± 0.08<sup>b</sup> | 7.19 ± 0.06<sup>b</sup> |               |               |          |
|                             | 9.98 ± 0.04<sup>g</sup> | 7.65 ± 0.09<sup>e</sup> | 7.23 ± 0.13<sup>b</sup> | 7.22 ± 0.12<sup>b</sup> |               |               |          |

Values are means of three replications ± standard deviation.
Data in same column with different letters are significantly different (P < 0.05).
NS: non-significant,
C: Control: tomato pulp without any treatment; L4: cut tomato pulp pretreated with 15% NaCl and 4% lemon juice; L6: tomato pulp pretreated with 15% NaCl and 6% lemon; L8: tomato pulp pretreated with 15% NaCl and 8% lemon (L8). FT, fresh tomato. All pretreatments were performed for 5 min.
content between 12 and 18% belong to the group of reduced dried tomatoes with a very firm texture. Preprocessed dried tomatoes range into this group because their water content fell within the limits. Those with a water content between 18 and 25% are part of the usual tomato group with a firm but pliable texture. The control dried tomatoes belongs to this group. The stability of the moisture content of the pretreated dried tomato slices could allow better preservation. It has been previously observed that dried tomato slices resulting from the various treatments of flexible and pliable texture retained water content of 24.76 to 47.11%. Farooq et al. found that the moisture content of powdered tomatoes increased with increasing storage period from 0 to 30 days. This increase during storage may be due to water vapor permeability of packaging material and hygroscopic nature of tomato powder.

The stability of the moisture content of the dried tomato slices is due to the preservatives (salt and lemon) used for the pretreatment. Pretreatment before drying could improve the characteristics of the process and reduce the negative effects of drying on the quality of a product. The reduction in the moisture content of dried tomatoes slices compared to fresh tomatoes will reduce the risk of tomato perishability. At t0, the pH was between 4.02 ± 0.01% for the L4 dried tomato slices and 4.19 ± 0.01% for the C dried tomato slices. The fresh tomato exhibited a pH of 4.17 ± 0.00. During storage (t0 to t6), the pH of the pretreated dried tomato slices did not significantly decrease, while for the control a decrease of 6.52% was observed.

Unlike pH, the total acidity of pretreated dried tomatoes slices increased significantly from 0.94 to 9.04% during storage (t0 to t6). Similar results on pH variation and titratable acidity were observed by Farooq et al. and Lisiewska & Kmiecik. The increase in titratable acidity and the decrease in pH may be due to the hydrolysis and de-esterification of pectin polysaccharides. For dried tomato slices C an increase of 10.55% was observed. The pH obtained at t0 is similar to that obtained by Agassounon et al. who found a value of 4.12 for dried tomato slices. The pH and total acidity of the lemon pretreated dried tomatoes slices show slight variation during storage compared to the control. The variation is proportional to the concentration of lemon used for the pretreatment. Being parameters of hygienic quality and physicochemical quality, their invariability is desired. Also, the relatively low pH of the pretreated dried tomato slices is an advantage from the point of view of product stability. Indeed, this pH level could considerably reduce the nature of the microorganisms that can grow on the product. Only acidophilic microorganisms, in particular: yeasts, molds, Acetobacters and Lactobacillus can grow there; but not Coliforms of the type Escherichia coli.

The total ash content of 4%, 6% and 8% lemon pretreated dried tomato slices showed a slight decrease during storage. The analyzes did not show a statistically significant difference between the samples of dried tomato slices pretreated during storage (P > 0.005). Similar results were reported by Farooq et al. during of 30 days storage on samples of powder from tomatoes pretreated with ascorbic acid and citric acid. Thus, the observed impact of lemon could be could due to its content in organic acids, notably citric acid (5–6%), ascorbic acid and its acidity (pH2).

The total ash content of the dried tomato slices without pretreatment decreased by 13.27% during storage. The total ash content of the lemon pretreated dried tomato slices was very high compared to that of the fresh tomato. The stability of the ash during storage of the samples of pretreated tomatoes could be due to the salt + lemon preservative used for the pretreatment. Also, the high total ash content of pretreated dried tomato slices may be due to the preservatives used for the pretreatment. Salt and lemon are preservatives that contain high levels of total ash.

**Color parameters (L*, a*, b*)**

With respect to color, changes lightness (L*), redness (a*), and yellowness (b*) were observed during storage with different levels according to pretreatments (Table 3). Color is one of the important attributes of a dehydrated product from a consumer perspective. For the value of the lightness (L*), it is higher for the pretreated dried tomatoes slices compared to the fresh tomato. It decreased from 3.03% for L6 dried tomatoes slices to 22.78% for control dried tomatoes slices during storage. For L8 dried tomato slices, it remained stable during storage. The redness (a*) decreased 19% for L4 dried tomatoes slices and 44.20% for control dried tomato slices and with an increase of 7.62 and 10.82% for
| Parameters | Time of storage | Signification |
|-----------|----------------|---------------|
|           | t₀ (0 month) | t₁ (01 months) | t₂ (02 months) | t₃ (03 months) | t₄ (04 months) | t₅ (06 months) |
| L⁺        | T             | 57.30 ± 0.19   | 51.96 ± 0.53   | 51.42 ± 0.58   | 51.78 ± 0.75   | 46.19 ± 1.17   | 44.25 ± 1.52   | ***          |
|           | L4            | 61.62 ± 0.56   | 58.31 ± 0.44   | 59.24 ± 0.53   | 58.38 ± 0.53   | 49.45 ± 0.60   | 51.80 ± 0.59   | **           |
|           | L6            | 63.57 ± 0.48   | 63.91 ± 0.22   | 62.38 ± 0.22   | 63.08 ± 0.28   | 62.29 ± 0.94   | 61.20 ± 0.27   | NS           |
|           | L8            | 64.14 ± 0.49   | 65.18 ± 0.83   | 62.49 ± 0.47   | 64.81 ± 0.72   | 64.86 ± 0.58   | 63.96 ± 0.42   | NS           |
|           | FT            | 36.81 ± 0.37   |                 |                |                |                |                |              |
| a⁺        | T             | 15.88 ± 0.09   | 13.45 ± 1.25   | 12.62 ± 0.55   | 12.70 ± 0.82   | 9.49 ± 0.92    | 8.86 ± 1.22    | ***          |
|           | L4            | 15.88 ± 0.25   | 15.84 ± 0.33   | 16.01 ± 0.57   | 14.70 ± 0.12   | 14.46 ± 0.24   | 12.86 ± 0.44   | **           |
|           | L6            | 14.98 ± 0.33   | 14.69 ± 0.56   | 14.49 ± 0.19   | 16.92 ± 0.52   | 16.25 ± 0.04   | 16.11 ± 0.16   | NS           |
|           | L8            | 14.61 ± 0.31   | 14.43 ± 0.20   | 14.45 ± 0.12   | 16.02 ± 0.32   | 15.91 ± 0.63   | 16.18 ± 0.25   | NS           |
|           | FT            | 15.46 ± 0.73   |                 |                |                |                |                |              |
| b⁺        | T             | 23.24 ± 0.26   | 19.45 ± 1.23   | 18.68 ± 0.51   | 17.77 ± 1.15   | 12.77 ± 1.62   | 8.91 ± 2.35    | ***          |
|           | L4            | 26.94 ± 0.50   | 23.81 ± 1.00   | 24.30 ± 1.12   | 24.13 ± 0.70   | 20.09 ± 0.85   | 18.69 ± 0.43   | **           |
|           | L6            | 28.92 ± 1.30   | 29.11 ± 1.13   | 28.49 ± 1.21   | 27.91 ± 1.42   | 28.06 ± 0.59   | 29.05 ± 0.45   | NS           |
|           | L8            | 31.74 ± 1.11   | 31.83 ± 0.09   | 30.26 ± 0.57   | 31.70 ± 0.13   | 31.72 ± 0.99   | 31.05 ± 0.22   | NS           |
|           | FT            | 14.13 ± 0.61   |                 |                |                |                |                |              |

Values are mean ± standard deviation of triplicates. Data in same column with different letters are significantly different (p < 0.05).
NS: non-significant; *P < 0.05; **P < 0.01; ***P < 0.001

C: Control: tomato pulp without any treatment; L4: cut tomato pulp pretreated with 15% NaCl and 4% lemon juice; L6: tomato pulp pretreated with 15% NaCl and 6% lemon; L8: tomato pulp pretreated with 15% NaCl and 8% lemon (L8); FT, fresh tomato. All pretreatments were performed for 5 min.
L6 and L8 dried tomato slices respectively. During storage, the parameter b* also decreased of 61.65% for control dried tomatoes slices and 30.61% for L4 dried tomato slices with a significant difference (P < .05). The yellowness (b*) of dried tomatoes slices was higher than that of fresh tomatoes. During storage no-significant difference (P > 0.05) in the values of the color parameters (L*, a*, b*) of L6 and L8 dried tomatoes slices was observed. For lightness (L*) values, samples L6 and L8 preserved it better during storage. For control and L4 dried tomatoes slices, its decrease during storage could be explained by the fact that there was darkening due to the browning reactions. With respect to the parameter a*, it is noted that for the control and L4 dried tomatoes slices, an influence on the red component of the color of the dried tomato slices was observed during storage. This could be explained by the fact that the lycopene responsible in part for this red color was degraded during storage. For the parameter b*, an increase was noted compared to the fresh tomato. The data shows that the fresh tomatoes were more yellow than red. It can therefore be assessed that they were orange. This could explain the strengthening of the orange color after drying. These results are similar to those of Kone.\textsuperscript{27} who had observed a decrease in lightness (L*), redness (a*) and yellowness (b*) values of freeze-dried and hot-air- dried tomato slices powder pretreated or not with the advancement of the storage period from 0 to 30 days.

Chroma parameters (C*, h*, a*/b*) also changed during storage (Table 4). At t0, the saturation of the red color is higher for L6 and L8 dried tomatoes slices compared to C and L4 dried tomatoes slices and even fresh tomato. During storage, chroma C* were subjected to a decrease of 27.39% and 60.02 for dried tomatoes C4 and control respectively with a significant difference (P < .05). A non-significant increase in saturation for L6 and L8 dried tomato slices was observed during storage. A higher tint angle h° of the dried tomatoes compared to the fresh tomato was observed. The h° tint angle of L6 and L8 dried tomatoes is higher than that of C and L4 dried tomatoes slices. During storage there was a decrease of 2.58% for L4 dried tomatoes slices and 6.44% for C dried tomatoes slices with a significant difference (P < 0.05). For L6 and L8 dried tomatoes slices, it remained stable. The value of the parameter a*/b* was lower for fresh tomatoes compared to dried tomatoes but there was no statistically significant difference between the value of parameter a*/b* of dried tomatoes slices and those of tomato fresh. For L6 and L8 dried tomatoes slices, it is significantly lower than that of control and L4. An increase from 7.13% for L6 dried tomatoes slices to 45.41% for control dried tomatoes slices was observed during storage.

The high C*chroma of L6 and L8 dried tomato slices shows that there was an improvement in saturation, the red color became more vivid and intense. During storage, for control and L4 dried tomatoes slices, it experienced a decrease which means that the red color became less saturated, that is, duller (darker). In this study, the h° hue of the dried tomato slices was higher than that of the fresh tomato. The tint angle for all dried tomatoes slices is closer to orange red (value below 54°). As for the fresh tomato, the h° value indicate red color (h° value of 46.16, ranging between 18° and 54°) as observed.\textsuperscript{28} The decrease in the tint angle h° of the dried tomatoes slices C and L4 during storage shows that there was a color change. The a*/b* parameter indicates good tomato quality when its value is low.\textsuperscript{29} After analyzing the a*/b* parameter, it appear that the dried tomatoes slices L6 and L8 are not different in color quality compared to the fresh tomato. Control and L4 dried tomatoes slices are darker. With regard to the color parameters measured, the 6% and 8% lemon pretreatment allows better preservation of the color of the dried tomatoes slices compared to the dried tomatoes slices without pretreatment and with 4% lemon pretreatment.

For all samples, the red color darkens with increasing storage time (Figure 1). It darkened considerably for the dried C samples and the L4 samples. The degree of color change is as follows: C> L4> L6> L8. The change in red color of dried tomatoes slices may be due to browning reactions, reactions due to degradation of pigments such as lycopene, xanthophyll, chlorophyll, total phenolic.\textsuperscript{30}

Figure 1 illustrates a view of dried tomatoes slice without pretreatment and those pretreated. For all samples the red color darkens with increasing storage time. It darkened considerably for the dried C samples and the L4 samples. The degree of color change is as follows: C> L4> L6> L8. The change in red color of dried tomatoes may be due to browning reactions, reactions due to degradation of pigments such as lycopene, xanthophyll, chlorophyll, total phenolic.\textsuperscript{30}
Table 4. Variation of the color parameters (C*, h*, a/b*) of the dried tomato slices of the different pretreatments during storage.

| Parameters | Time of storage |
|------------|-----------------|
|            | t0 (0 month)    | t1 (01 month)   | t2 (02 months)  | t3 (03 months)  | t4 (04 months)  | t6 (06 months) |
| C*         |                 |                 |                 |                 |                 |                |
| T          | 28.14 ± 0.26a   | 23.65 ± 0.72d   | 22.54 ± 0.72d   | 21.84 ± 1.37d   | 15.89 ± 1.85a   | 11.25 ± 2.61b  |
| L4         | 31.38 ± 0.30gh  | 28.61 ± 1.00e   | 29.10 ± 1.25e   | 28.84 ± 0.12e   | 28.52 ± 0.73e   | 22.79 ± 0.59d  |
| L6         | 32.58 ± 1.00gh  | 32.62 ± 0.87ghi | 32.92 ± 1.00ghi | 31.20 ± 1.08ghi | 31.91 ± 0.49g   | 33.22 ± 0.44g  |
| L8         | 34.93 ± 0.90h   | 34.95 ± 0.08k   | 34.44 ± 0.51jk  | 34.66 ± 0.23k   | 34.57 ± 1.14k   | 35.02 ± 0.08k  |
| FT         | 20.98 ± 0.37a   |                 |                 |                 |                 |                |
| h°         |                 |                 |                 |                 |                 |                |
| T          | 55.66 ± 0.16gh  | 55.36 ± 0.84efg | 55.96 ± 0.53efh | 54.43 ± 0.89de  | 53.42 ± 0.79cd  | 52.07 ± 2.07c  |
| L4         | 59.13 ± 0.86m   | 56.36 ± 0.58gh  | 56.61 ± 0.26gh  | 56.81 ± 0.13gh  | 54.56 ± 1.57def | 55.12 ± 0.42deg |
| L6         | 62.59 ± 1.60km  | 63.20 ± 1.59im  | 59.93 ± 1.23hi  | 63.44 ± 1.94hi  | 63.45 ± 0.61f   | 60.98 ± 0.29k  |
| L8         | 65.25 ± 1.16n   | 65.61 ± 0.34n   | 61.47 ± 0.49n   | 66.14 ± 0.42n   | 66.14 ± 0.47n   | 62.47 ± 0.53n  |
| FT         | 48.16 ± 0.68ab  |                 |                 |                 |                 |                |
| a/b*       |                 |                 |                 |                 |                 |                |
| T          | 0.68 ± 0.00d    | 0.69 ± 0.02hi   | 0.68 ± 0.01ghi  | 0.71 ± 0.03j   | 0.74 ± 0.02jk   | 0.99 ± 0.06k   |
| L4         | 0.59 ± 0.02     | 0.67 ± 0.01gh   | 0.66 ± 0.01gh   | 0.61 ± 0.00gh   | 0.72 ± 0.04j   | 0.69 ± 0.01k   |
| L6         | 0.52 ± 0.04     | 0.50 ± 0.03c    | 0.58 ± 0.03cd   | 0.61 ± 0.06c   | 0.59 ± 0.01cd   | 0.55 ± 0.01de  |
| L8         | 0.46 ± 0.02ab   | 0.45 ± 0.01a    | 0.54 ± 0.01ab   | 0.51 ± 0.01a   | 0.52 ± 0.01ab   | 0.52 ± 0.01ab  |
| FT         | 0.41 ± 0.02     |                 |                 |                 |                 |                |

Values are mean ± standard deviation of triplicates. Data in same column with different letters are significantly different (p < 0.05). NS: non-significant, *P < 0.05; **P < 0.01, ***P < 0.001; C: Control: tomato pulp without any treatment; L4: cut tomato pulp pretreated with 15% NaCl and 4% lemon juice; L6: tomato pulp pretreated with 15% NaCl and 6% lemon; L8: tomato pulp pretreated with 15% NaCl and 8% lemon (L8). FT, fresh tomato. All pretreatments were performed for 5 min.
**β-carotene and Lycopene**

The β-carotene contents of the control dried tomatoes slice and the pretreated dried tomatoes slice decreased during the six months of storage (Figure 2). The β-carotene content of the control pretreated dried tomatoes slices decreased more (60.89%) compared to those of the pretreated dried tomatoes slices (26.04% for L6, 34.61% for L4 and 29.06 for L8). The fresh tomato had the highest β-carotene content compared to the control and pretreated dried tomatoes slices. Statistical analyzes showed a significant difference in the β-carotene content of dried tomatoes slices during storage.

The lycopene content of control C dried tomatoes slices and L4 pretreated ones decreased by 59.53 and 47.88% respectively during storage (Figure 3). For the L6 and L8 pretreated dried tomatoes, their lycopene content did not show any significant difference (P < .05) during storage. Also, the lycopene content of the fresh tomato was higher than that of the control and pretreated dried tomatoes.

There was a stability of the lycopene content and a slight decrease in the β-carotene content of all the pretreated dried tomato slices during storage compared to the control dried tomatoes. This could be due to the salt + lemon preservatives used for the pretreatment. The decrease during storage compared to fresh tomato could be due to the heat that was applied during drying. Other factors may contribute to the decrease in the initial β-carotene content in tomatoes. On the one hand, these are the extremely variable losses that occur during soaking. Prolonged heating seems to promote isomerization based on the destructuring of the food matrix and oxidation, which is favored by contact with air combined with high water activity.\(^{24}\) Soria et al.\(^{31}\) reported that dehydrating conditions can subsequently cause the breakdown of carotenoids.

Farooq et al.\(^{14}\) found a decrease in Lycopene content during storage in freeze-dried powdered tomatoes and hot air dried pretreated and not pretreated. The degradation of lycopene during storage according to them could be due to isomerization and oxidation. similar results have been reported by Akanbi & Oludemi\(^{32}\) where they explained that lycopene in stored tomato degrades depending on temperature and time of storage. Farooq et al.\(^{4}\) have shown that the use of pretreatments minimizes thermal degradation and oxidation of carotenoids and act as an inhibitor of browning reactions. The degradation of β-carotene during storage may be due to extrinsic factors, such as severity of heat treatment, presence or absence of light, storage temperature, packaging.\(^{5}\) It may also be due to the characteristics of food matrices, such as their chemical composition, the oxygen dissolved in the sample.\(^{33}\)

![Figure 2](image.png)

**Figure 2.** Change of the β-carotene content of dried tomato slices during storage. Error bars indicate the standard deviation. Data points marked with the same letter are not significantly different (p < 0.05). C: Control; tomato pulp without any treatment; L4: cut tomato pulp pretreated with 15% NaCl and 4% lemon juice; L6: tomato pulp pretreated with 15% NaCl and 6% lemon; L8: tomato pulp pretreated with 15% NaCl and 8% lemon (L8). FT, fresh tomato. All pretreatments were performed for 5 min.
**Figure 3.** Variation of lycopene content in dried tomato slices during storage. Error bars indicate the standard deviation. Data points marked with the same letter are not significantly different (p < 0.05). C: Control: tomato pulp without any treatment; L4: cut tomato pulp pretreated with 15% NaCl and 4% lemon juice; L6: tomato pulp pretreated with 15% NaCl and 6% lemon; L8: tomato pulp pretreated with 15% NaCl and 8% lemon (L8). FT, fresh tomato. All pretreatments were performed for 5 min.

**Total phenolic**

During the six months of storage (t1 to t6), the total phenolic content of the control C dried tomato slices and the L4 pretreated ones decreased (Figure 4). The change in the content of phenolic compounds during storage can be explained by the oxidation mechanisms, and in particular the enzymatic oxidation, of total phenolic described by Guyot et al.\textsuperscript{[34]} For L6 and L8 pretreated dried tomatoes, their total phenolic content remained stable (Figure 4). There was no significant difference (P < 0.05) during storage. The stability of the total phenolic content can be explained by the concentration of lemon juice (6% and 8%) used for the pretreatment. The higher the concentration of lemon, the more there is a stability of total phenolic. The total phenolic content of fresh tomato was lower than that of dried tomatoes.

**Figure 4.** Change of total phenolic content of dried tomato slices during storage Error bars indicate the standard deviation. Data points marked with the same letter are not significantly different (p < 0.05). C: Control: tomato pulp without any treatment; L4: cut tomato pulp pretreated with 15% NaCl and 4% lemon juice; L6: tomato pulp pretreated with 15% NaCl and 6% lemon; L8: tomato pulp pretreated with 15% NaCl and 8% lemon (L8). FT, fresh tomato. All pretreatments were performed for 5 min.
Conclusion

The results showed that the stored dried tomatoes slices without pretreatment showed lower physicochemical and nutritional qualities than pretreatment with lemon and salt. Pretreated tomato slices with 6 to 8% of lemon and 15% salt prior to drying preserved physicochemical characteristics and nutritional qualities during storage. This convenient and simple technique can be recommended to produce high quality dried tomato slices with long shelf life.

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Disclosure statement

No potential conflict of interest was reported by the author(s).

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