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**The Effects of Skin and Seed Removal of Tomato Fruits for the Home Canning
Process on Texture and Nutritional Value**

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Master of Science in
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ABSTRACT**The Effects of Skin and Seed Removal of Tomato Fruits for the Home Canning Process on Texture and Nutritional Value****Emilie S. Burgess**

Tomatoes are consumed all over the world, but mainly after the tomatoes have undergone processing. Approximately three quarters of tomatoes consumed within the US are processed. A review of the scientific literature was conducted to investigate nutrient losses caused by the current tomato canning process. The bulk of tomatoes nutrients and health benefits are within the skin and seed components, and currently both are removed for home and commercial canning process. Studies showed that the current tomato canning protocol used by home canners and industries resulted in substantial nutrient loss due to removing the skin and the seeds before placing the fruit into cans. A revised 'health conscious' tomato canning protocol is proposed, discussing its advantages on nutrient and phytochemical retention. Leaving the skin and seeds intact when canning tomatoes allows for a higher retention of nutrients, phytochemicals, and eliminates waste. No studies have investigated an alternative to the current tomato canning protocol. A revised 'health conscious' protocol will spare the removal of the skin and the seeds, allowing for the preservation of nutrients during the canning process. More research with a revised 'health conscious' protocol will help industries and home canners preserve a higher yield of nutrients and to make a more educated decision regarding how to preserve their tomatoes.

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Introduction

Tomatoes are known as a health-promoting fruit due to their high composition of bioactive compounds such as tocopherols, polyphenols, lycopene, and ascorbic acid.¹¹ Consumption of tomatoes worldwide is mainly as pulp or cooked after the skin and seeds have been removed.¹¹ The skin and the seeds are thought to be indigestible, lack palatability, and are low in nutrients by consumers.¹⁰ Yet, the skin and seed fractions of a tomato has significantly higher levels of nutrients compared to the pulp fraction of the fruit.¹⁰ Therefore, it is important to consume the whole tomato.

Tomatoes commonly undergo processing either industrially or at home which can alter the nutritional value of the fruit. Home canning is a common processing method used to preserve tomatoes.¹⁰ In modern food technology, maximizing nutrients during storage is the trend, but the current protocol for tomato canning decreases key nutrients before the fruits are sealed into jars.⁷ These key nutrients include lycopene, polyphenols, and β -carotene. The current canning protocol can influence nutrient retention through the steps of cutting, blanching, and peeling.¹ Studies on the effects of food processing and home canning demonstrated that removing the peel and seed portions was nutritionally detrimental in the tomato canning process. This suggests there is a need for a revised 'health conscious' tomato canning protocol.⁶⁻¹¹ The skin of a tomato fruit contain high levels of carotenoids such as lycopene and β -carotene which have been correlated to lower incidences of prostate cancers.^{5,9} Lycopene can lower oxidative stress through antioxidant activity and gene regulation, but the biological activity of lycopene relies on the bioavailability of the nutrient.⁹

The skin and seeds of a tomato are the main contributor to the overall antioxidant activity of tomatoes and thus, during processing neither should be removed.¹⁰ The current protocol for canning tomato fruits involves trimming and blanching which removes the skin and seeds in the process. There are few studies comparing canning protocols of tomatoes with and without the skin and seeds. This paper is intended to review the effects of removing the skin and seeds of tomatoes with the current canning protocol and the development of a new revised 'health conscious' home canning method.

Literature Review

Health Benefits of Tomatoes (Skin, Seeds, and Pulp)

Whole tomato fruits contain high levels of minerals and phytochemicals.¹⁻⁶ The tomato fruit is a reservoir of diverse antioxidant nutrients such as ascorbic acid, vitamin E, carotenoids, flavonoids, and phenolic acids.⁹⁻¹¹ All three parts of a tomato; skin, seeds, and pulp, contain phytochemicals but in different amounts. It has been shown that the skin and seed fractions of a tomato contributed higher levels of phenolics (53%), flavonoids (52%), lycopene (48%), ascorbic acid (43%), and antioxidant activity (52%) compared to the pulp.¹⁰ Toor and Savage calculated the amount of antioxidants in each fraction based on their fresh weights in a whole tomato. Evaluation of three different tomato cultivars showed that seeds and skin contributed to greater than 40% of total flavonoids, lycopene, ascorbic acid, and total antioxidants.¹⁰

In the tomato, lycopene is the main carotenoid with antioxidant properties. Lycopene has been shown to lower the risk of developing pancreas, breast, and prostate cancers both *in vitro* and *in vivo*.⁵ In addition, lycopene has been shown to induce cell-to-cell communication and to modulate hormones, immune systems, and other metabolic

pathways.⁵ The skin of a tomato contains 2.5 times the lycopene content of the pulp.⁵ Binoy et al. reported that tomato skin and seeds have 3 times more lycopene compared to the pulp.⁵ Furthermore, tomato skin and seeds were reported to contain essential amino acids and high amounts of minerals including: zinc, manganese, copper, and iron, that also function as antioxidants within the body.¹⁰ Each part of the tomato contains different concentrations of health benefiting nutrients with the majority of the nutrients found within the skin and seeds. Tomatoes have disease preventing effects due to synergistic interactions between several nutrients within the fruit.⁵ Synergistic effects could lead to the combination of two or more compounds within a tomato to enhance the neutralizing effect of free radicals by antioxidants.⁵ Therefore, the entire fruit should be consumed to obtain the full health benefits that a tomato can provide. Increasing consumer knowledge about the nutritional benefits of consuming a whole tomato can lead to alterations in the methods of tomato processing and hence, increase nutrient intake.

During processing one third of a tomatoes total weight is discarded and nutrients may be lost.⁶⁻¹⁰ Tomato sauce or paste are the two most common forms in which tomatoes are purchased and consumed.⁵⁻⁶ There is a misconception of where the majority of the nutrients within a tomato are located. When tomatoes are processed, the skin and seeds are generally removed due to the perception that these are indigestible and contain low levels of nutrients.¹⁰⁻¹¹ Due to the high levels of vitamins, minerals, and phytochemicals within the skin and seeds of a tomato, removing these during processing may cause reduced nutritional value and a loss of health benefits to the consumer. If slight changes are made to tomatoes processing then the antioxidant and nutrient composition of the final product may be increased and the nutritional content would be optimally utilized.¹⁰

Nutrient Losses Due to Canning Procedures

Processing of tomatoes can be done either industrially or at home. The current protocol for tomato processing involves operations such as heating, blanching, and canning where the skin and seeds are removed.¹¹ Since tomatoes are mainly consumed without the skin and seeds and mainly from canned tomato products, the consumer is potentially missing out on important nutrients that tomatoes naturally contain.⁹⁻¹¹ Vinha and Alves evaluated antioxidants in homogenized tomato samples by measuring scavenging of 2,2-diphenylpicrylhydrazyl (DPPH) free radical and coupled oxidation of β -carotene and linoleic acid. The results showed that peeling and removing the skin causes a 23% decrease while removing the seeds caused a 7% decrease in the tomatoes antioxidant content. Results demonstrated that skin removal was more detrimental than seed removal.¹¹

Home canning of tomatoes is a popular method of preservation. The goal of home canning and other tomato processing methods is vitamin retention within the final product which is the degree of vitamin conservation attained during the operations of converting raw material into the finished canned product.¹ During canning, tomatoes undergo multiple steps leading up to the final canned product. Experiments have been performed to determine which steps during the preparation and processing of canned food products were the most detrimental, and found that trimming than blanching lead to the highest nutrient loss.¹⁻⁵

Blanching is one of the main steps in the current canning protocol for tomatoes.¹⁻⁵ The blanching process involves placing the tomatoes into boiling water to preserve the flavor of the fruit.⁵ Thermal treatments such as blanching can adversely affect both

nutritive and sensory qualities of tomato fractions.² This is due to the redox reactions which changes sensory aspects such as mouth feel and nutritive qualities of the tomato include decrease carotenoids and polyunsaturated fatty acids.² Blanching also leads to non-enzymatic Maillard reaction activation and polyunsaturated fatty acid oxidation resulting in changes in volatile compounds.²

Canning of tomatoes allows for retention of nutrients, but the preparation methods can affect the nutrient content even before the produce is placed into cans.¹⁻⁵ The trend in food technology is to maximize nutrient retention during processing and storage, yet the current canning method causes large decreases in vitamin and mineral content of the fruit.⁷ The goal of canning is to preserve tomatoes for an average of a year in a dry cool storage location, but currently nutrients are being lost at the initial steps in canning which decreases the overall health benefits of the fruit even before preservation and storage begins.

Current Tomato Canning Protocol

Home canning is a safe and economical way to preserve food quality at home. Collectively, the steps of home canning removes oxygen, destroys enzymes, preserves nutrients, and prevents the growth of microorganisms.⁴ The process of canning tomatoes begins with cleaning of the tomatoes by rinsing in cold water. After the tomatoes have been washed, the fruits are then dried and trimmed. The process of trimming includes removing the stem and a shallow “X” is sliced on the bottom to assist with the release of the skin from the tomato for the next processing steps.

In current canning protocols, blanching is the first step in canning where tomatoes are placed into boiling water for approximately 30 seconds then removed and placed into

an ice bath for about 30 seconds. The skin and seeds are then removed before placing the tomatoes into the sterilized cans. Hot water is then poured over the tomatoes leaving about one inch of headspace at the top of the jar (Figure 1).⁴ The headspace is needed to allow for expansion of the tomatoes as the jars are processed and for formation of a vacuum in cooled jars.⁴ The jar is wiped dry, a ring and lid are placed on⁴. The can is placed into a boiling-water canner, process for 40 minutes, and then the lids sealed shut.⁴ Tomatoes are high in acid ($\text{pH} < 4.6$) and therefore, can be processed using either a boiling water canner (Figure 2) or a pressure canner.⁴ High acid foods can be processed using either boiling water canning or pressure canner due to lower risk of becoming contaminated with foodborne pathogens or toxins, compared to low acid foods.⁴

Figure 1.
Home Canning Headspace. Adapted
from (Andress et al, 2004)

Figure 2.
Processing in Boiling Water Canner.
Adapted from (Andress et al, 2004)

When tomatoes are placed into the jars, hot water packing is the preferred method for foods that are processed using a boiling-water canner.¹⁻⁴ Hot water packing entails

pouring hot water over the food product within the can.¹⁻⁵ The current canning protocol requires the skin and seeds to be removed after the tomato has been removed from the ice bath. Comparatively, blanching results in minor nutrient loss while removal of skin and seeds can cause major nutrient losses.¹⁻⁵ The goal of canning is to preserve nutrients, flavor, and texture of a tomato for extended periods of time; however, the preparation methods for tomato storage cause losses. Therefore, a revised 'health conscious' protocol needs to be proposed to prevent nutrient loss in the processing of canning.

Development of a Revised Tomato Canning Protocol

The processing of tomatoes has remained unchanged for hundreds of years, but advances in technology and research have demonstrated that the current protocol was not developed with preserving nutritional value as a goal. Instead, the original goal was to preserve the flavor and texture of the tomato through blanching, trimming, and hot packing. Small changes to existing canning protocol can prevent loss of vitamins, minerals, and phytochemicals.⁴⁻⁷ Therefore, current protocols should be revised in order to maintain the highest nutrient retention in the final product.

In the current canning protocol, trimming of the tomato involves removing the stem and carving an "X" on the bottom to promote skin falling off during the blanching process. For the purpose of preventing loss of nutrients, the revised canning protocol will entail removing the stem, but an "X" will not be carved on the bottom in order to keep the skin on the tomato during further processing.

Blanching is the next step in tomato processing and causes minor nutrient loss when tomatoes are placed into boiling water.¹⁻³ Tomatoes are blanched before they are canned in order to destroy active enzymes and to retain the overall flavor of the fruit. The

revised protocol will include the blanching step for peak flavor retention. However, post-blanching, tomatoes are placed into an ice bath. This step also encourages the skin to fall off of the fruit. Therefore, in the revised canning protocol an X is not carved into the bottom of the fruit so the skin stays intact during the heat and ice bath treatments.

The next step in existing protocol is peeling the skin and removing the seeds of the fruit. For the revised canning protocol, the skin and seeds is left on the fruit to preserve nutrients. Toor and Savage reported that retaining the skin and seed fractions during the home consumption or processing results in a 40-53% increase in the amount of all major antioxidants including: lycopene, phenolics, flavonoids, and vitamins C and E.¹⁰ Skipping the post-blanching trimming step will allow for further nutrient retention. The tomatoes, with peel and skin both intact will be placed into the jars for hot water packing. In the final processing step, the cans are placed into the boiling water canner. Utilizing the revised health conscious protocol for canning tomatoes, more nutrients can be retained through both the preparation steps and throughout the process. Home processing methods are common, and changing steps to reduce nutrient loss can lead to a healthier final product.

Conclusion/Recommendations

Tomatoes have a complex matrix of nutrients with health promoting properties. To obtain all of the nutrients tomatoes should be consumed whole. Canning is a process that has been used for hundreds of years for preserving a wide variety of foods. Existing canning protocol for tomatoes causes nutritional losses to the fruits, and decreases the antioxidant content.¹⁻¹¹ Revising existing tomato canning protocols to retain skin and seeds may prevent nutrient loss to provide consumers with the highest nutritional value.

Both home canning and industry may be able to benefit from a revised health conscious protocol based on providing the consumer with the highest possible nutrient content.

Pilot Study

Hypothesis: Leaving the skin and seeds intact during tomato canning allows for higher nutrient retention in the final product.

Objectives:

- 1.) To measure the nutrients retained and lost during the canning process compared to a fresh tomato.
- 2.) To measure nutrients retained when skin and seeds are left on during canning, and what nutrients are lost when the skin and seeds are removed.
- 3.) To propose a revised ‘health conscious’ canning protocol for tomatoes

Experimental Design:

Raw materials and processing:

Figure 3: Processing and Canning Design for the Utilization of Two Tomato Canning Protocols

Tomatoes included two cultivars. ‘Arkansas Traveler’ was selected primarily because it is a common heirloom produced by small scale Community Supported

Agriculture's (CSAs), it was still prolific late in the growing season, and it possess horticultural traits valued by producers. These traits include color, size, uniformity or ripening, and flavor. 'Arkansas Traveler' tomatoes were grown and harvested from West Virginia University's Organic Farm located in Morgantown, WV. The 'Arkansas Traveler' tomatoes were grown organically without the use of synthetic pesticides, which best represents the production practices of small and local gardens. 'Grainger' varies in regards to size, color, and uniformity of the 'Arkansas Traveler.' 'Grainger' was donated by a WVU Faculty member. 'Grainger' tomatoes were produced conventionally in Tennessee. Both tomato cultivars were collected at the end of their growing seasons and thus, large quantities of both tomato cultivars were limited.

Shown in Figure 3, tomatoes (n=30) were divided into two canning treatment groups. Tomatoes in Group 1 were processed using the current tomato canning protocol and tomatoes in Group 2 are to be processed using a revised 'health conscious' protocol. The two groups of tomatoes were then separated into four jar replications (n=4 tomatoes/jar); all tomatoes will be processed together within the group, then are separated into four different jars for storage.

Preparation Methods:

1.) Fresh:

1. Collect starting weight for each tomato sample
2. Rinse in cold water
3. Cut out stem
4. Cut Tomato into quarters
5. Weigh each tomato slice

2.) Control Group

Freeze-dried frozen tomatoes were prepared as the control for comparison to the canned stored tomatoes. Fresh batches of both 'Arkansas Traveler' and 'Grainger'

tomatoes were cut and placed on large trays to be freeze-dried for 3 days in a VirTis Freeze Drier Product (Model #35L Genesis SQ Super XL-70, SP Scientific, Stone Ridge NY). After freeze-drying was complete, tomato cultivars were separated into four replications (individual bags). The freeze-dried tomatoes were placed into four separate zip lock bags and stored in an -80°C freezer until analyzed.

3.) Current Home Canning Protocol (Figure 4)

Stepwise:

1. Prepare boiling water canner. Heat jars in simmering water until ready for use. Do not boil. Wash lids in warm soapy water and set bands aside.
2. Wash tomatoes. Cut out stems off all tomatoes, and cut a shallow X on the bottom of the tomatoes to be canned.
3. Blanch in boiling water for 30 to 60 seconds after water returns to a boil.
4. Remove the tomatoes from the boiling water, and place them into cold water with ice for 30 seconds. Then remove from ice bath and place on cutting board for continued cooling.
5. Once tomatoes have cooled, remove the skin off the tomatoes and discard the peels.
6. Cut the tomatoes in half, and scoop out the seeds in the core of each half and discard.
7. Cut the tomatoes halves in half and weight out 300g of slices that will be placed into a jar (300g per jar).
8. Add 1/4 tsp Citric Acid or 1 Tbsp bottled lemon juice to each hot pint jar.
9. Pack tomatoes into the hot jars, adding 1/2 tsp of salt to each jar, and leaving one-inch headspace. Ladle hot water over the tomatoes leaving one-inch headspace.
10. Remove the air bubbles. Wipe rim, Center hot lid on jar. Apply band and adjust until fit is fingertip tight.
11. Process filled jars in a boiling water canner for 40 minutes for pints. Remove jars and cool. Check lids for seal after 24 hours. Lid should not flex up and down when center is pressed.

4.) Revised 'Health Conscious' Tomato Canning Protocol (Figure 5).

The Health Conscious Protocol has alterations to the above protocol at step

2 Wash tomatoes and cut out stems off all tomatoes.

5 and 6 Once tomatoes have cooled, cut the tomatoes into quarters, leaving the skin and seeds intact.

7 Weigh out 300g of tomato slices with intact skin and seeds to place into a jar (300g per jar).

Figure 4. Current Home Canning Protocol Process

Figure 5. Revised 'Health Conscious' Protocol Process

Materials and Methods

Color Analysis

Color was assessed on fresh batches of 'Arkansas Traveler' and 'Grainger' cultivars within 2 weeks of collection. All tomatoes were sliced into quarters for testing at room temperature ($\sim 25^{\circ}\text{C}$). Analysis was done in triplicates ($n=4$ tomato slices). Color was measured using a colorimeter (Minolta Camera Co Ltd, Osaka, Japan) calibrated with a standard white plate No.21333180 (CIE L^* 93.1, a^* 0.3135, b^* 0.3198) recording L^* , a , and b values. The colorimeter was measured on the inside surface of each tomato slice sample and four replications of data readings was taken for each sample. Value a represents a red to green ratio. A higher a value represents more red in

the sample, where a low value of a represents more green in the sample. Value b represents a yellow to blue ratio. A higher b value represents more yellow whereas a lower b value represents more blue in the sample. The L^* value is a representation of lightness to darkness. A higher L^* for lighter and lower L^* for darker. Figure 6 depicts the Hunter color scale readings for samples using the colorimeter.

Figure 6

Texture Analysis

For texture analysis of the tomato samples, a texture analyzer (TA-DHi, Texture Tech. Corp, Hamilton, MA) was utilized. Shear force was measured using an Allo-Kramer attachment. The shear force is a measure of firmness calculated by peak force divided by the weight of a sample (g/g wt). The Kramer-shear test was performed using 20g tomato slice samples measured in triplicates. Each triplicate (n=4 tomato slices) used a new tomato slice sample and a small plastic box was placed underneath the stage of the machine to catch any tomato juice or parts that was pushed off the stage. Compression analysis or ‘one bite test’ mimics biting action. Compression measures the total force needed to compress the tomato slice sample. The compression test was performed using 20g tomato slice samples measured in triplicates.

Statistics

All data is reported as the mean $\pm$ standard deviation for three replicates (n=4 slices). Two Tailed T-Tests were used at $p < 0.05$ and were calculated using Excel for Mac 2011 (Version 4.1.0) to determine significant differences between the two cultivars.

Preliminary Results/Discussion

Table 1 shows color analysis. ‘Arkansas Traveler’ had significantly ($p < 0.001$) higher L^* readings which indicated that the colors were significantly lighter than the ‘Grainger’ tomatoes. The ‘Grainger’ tomatoes had significantly higher readings for both a which indicated that the ‘Grainger’ contained significantly more red while ‘Arkansas Traveler’ tomatoes contained significantly more green. ‘Grainger’ tomatoes also had significantly higher readings for b , expressing significantly more yellow while the ‘Arkansas Traveler’ cultivar contained significantly more blue.

These variations in color can be due to the cultivars growing climates, harvesting time, storage methods, or uses of conventional or organic farming.¹⁰ The differences in the colors of the tomatoes could be due to the variation of nutrients in each cultivar. The ‘Grainger’ cultivar resulted in higher a value expressing stronger hues of the color red, meaning that the cultivar may contain more lycopene than the ‘Arkansas Traveler’ cultivar. Color differences in tomatoes can also be due to timing of harvest such as allowing one cultivar to fully mature compared to the other. When tomato fruits are picked at the peak of the growing season, the fruits texture and color had a longer period of time to develop and thus, more phytochemicals are present.⁷⁻¹⁰ The more time that the fruits have to ripen the more mature and brighter the colors become. With less maturity of the fruit, colors appear deeper in blues and greens, where tomatoes that have fully

matured express shades of reds and yellows. For the consumer, color is a major factor in the selecting and purchasing process. Consumers shop with their eyes, and are drawn to products with vibrant color.⁶ Based on the color data, the ‘Grainger’ cultivar is more desirable to consumers.

Table 1. Color Analysis of Two Tomato Cultivars

Tomato Cultivar	L*	a	b
‘Grainger’	41.87±1.94 ^b	23.25±2.59 ^a	14.47±1.38 ^a
‘Arkansas Traveler’	53.32±2.67 ^a	13.13±3.12 ^b	9.10±2.19 ^b

(Data are means ± standard deviation, different letters a, b in the same column indicate significant difference at $p < 0.001$ by Two-Tailed T-Test)

Table 2 shows texture analysis. Measurement of Shear force, the ‘Grainger’ tomatoes had significantly higher firmness compared to the ‘Arkansas Traveler’ cultivar. This indicated that the ‘Grainger’ tomatoes have a higher maximum shear stress that is sustained before the tomato ruptures. When compression was measured, ‘Grainger’ tomatoes had a significantly higher compression compared to the ‘Arkansas Traveler’ cultivar. This indicated that the fresh ‘Grainger’ tomatoes have a stronger crush resistance compared to the fresh ‘Arkansas Traveler’ tomatoes. Compression relates to tenderness, toughness, and overall pressure resistance, where Shear force is durability, tensile strength, and firmness.

The maturity and harvesting time can impact texture analysis of firmness, crispness, and resistance to pressure of the tomato fruit. The ‘Grainger’ tomatoes resulted in higher compression meaning that tomato is more durable and tough compared to the ‘Arkansas Traveler’. The ‘Grainger’ cultivar was grown conventionally using fertilizers;

this may have impacted how the surface of the tomato developed.⁸⁻¹¹ The ‘Arkansas Traveler’ tomatoes were grown organically, and were picked late in the growing season. This could have decreased tensile strength of the skin. The ‘Grainger’ cultivar also had significantly higher shear force values. The ‘Grainger’ cultivar has a stronger surface that is firmer compared to the ‘Arkansas Traveler’ cultivar. Consumers prefer tomato fruits that are durable, with a strong outer layer for a crisp bite when consumed. Based on texture analysis data, the ‘Grainger’ cultivar is more desirable to consumer.

Table 2. Texture Analysis of Two Tomato Cultivars

Tomato Sample	Shear Force (g of peak pressure/g of sample)	Compression Force (g)
‘Grainger’	280.26±93.07 ^a	53706±13905 ^a
‘Arkansas Traveler’	227.93±55.45 ^b	16817±3283 ^b

(Data are means ± standard deviation, Two-Tailed T-Test, a, b indicate difference at $p < 0.05$)

When selecting a tomato cultivar for canning either at home or in industry, tomatoes that are firm, durable, and have bright mature colors will contain more nutrients and will keep their shape and form during the canning process. The ‘Grainger’ cultivar showed significantly brighter colors of red and yellow, along with a strong outer layer that is considered desirable by producers.⁶

Future Research:

Future studies should compare the nutritional value between peeled and unpeeled tomatoes, using both the current and revised protocols to demonstrate which method of canning results in the highest nutrient retention. The research will be able to identify steps where there is nutrient loss, and if a revised ‘health conscious’ protocol yields a

higher nutrient retention. Future studies can also compare the two canning methods using organically and conventionally grown tomatoes on nutrients before and after treatment. This would be done through selecting tomato cultivars, then grow them both conventionally and organically. The tomatoes would then be canned using the current and revised health conscious protocol for future nutritional analysis. Performing actual sensory evaluations for texture and flavor would be able to identify sensory attributes that consumers value, instead of only relying on texture analysis. Future research on canning methods may provide evidence to support using the whole tomato during processing in order to retain the nutrients provided in tomatoes since various nutrients are stored in the skin of the fruit.

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