



COLOR DEGRADATION DURING STORAGE OF SWEET CORN KERNELS IN
BRINE PACKED IN SEMI-RIGID CONTAINER TREATED BY DIFFERENT
HEAT TREATMENTS

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Abstract

Color change of sweet corn kernels in brine during storage takes place when the kernels are packed in semi-rigid containers. This study investigated the effects of sterilization time and storage temperature on color change of sweet corn in brine packed in retortable carton. The work was divided into 2 parts. The first part was concerned with the effect of sterilization time (16 and 20 minutes at 122°C) and the second part of the study investigated the effect of storage temperature (30, 40 and 50 °C) on product qualities, as indicated by the change in color (CIE L^* , a^* and b^*), reducing sugar content, total carotenoid content, browning index and the total soluble phenolics content. It was found that rapid losses of color, total soluble phenolics and reducing sugar occurred when the long sterilization time (20 minutes) was used. Evolutions of carotenoid content of whole sweet corn kernels during storage showed no significant differences among samples stored at the three storage temperatures studied. It could be concluded that autoxidation of phenolics and non-enzymatic browning reaction were the major causes of browning of sweet corn in brine packed in semi-rigid containers. The reaction might take place during an initial stage of processing and continued under the influence of storage temperature. Experiments were also conducted to find an appropriate anti-browning agent for browning inhibition of the product but no successful results were achieved.

Keywords: Color degradation/ Kinetics/ Semi-rigid Container/ Storage/ Sweet Corn

หัวข้อโครงการศึกษาวิจัยพิเศษ	การศึกษาการสลายตัวของสีเมล็ดข้าวโพดหวานในน้ำเกลือ บรรจุในภาชนะกึ่งอ่อนตัวระหว่างการเก็บรักษาเมื่อใช้ ระยะเวลาในการให้ความร้อนต่างกัน
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บทคัดย่อ

การเปลี่ยนสีของเมล็ดข้าวโพดหวานในน้ำเกลือเกิดขึ้นเมื่อบรรจุผลิตภัณฑ์ในภาชนะบรรจุกึ่งอ่อนตัว งานวิจัยนี้จึงศึกษาผลของระยะเวลาในการให้ความร้อนและอุณหภูมิในการเก็บรักษาที่มีต่อการเปลี่ยนสีของผลิตภัณฑ์ โดยแบ่งการทดลองออกเป็น 2 ส่วน ส่วนแรกเป็นการศึกษาผลของระยะเวลาในการให้ความร้อน (16 และ 20 นาที ที่อุณหภูมิ 122 องศาเซลเซียส) สำหรับส่วนที่สองเป็นการศึกษาผลของอุณหภูมิที่ใช้ในการเก็บรักษา (30, 40 และ 50 องศาเซลเซียส) ที่มีต่อคุณภาพของผลิตภัณฑ์ซึ่งแสดงในรูปของค่าสี (CIE L^* , a^* , b^*) ปริมาณน้ำตาลรีดิวซ์ ปริมาณสารแคโรทีนอยด์ ดัชนีการเกิดสีน้ำตาลและปริมาณฟีนอลิกที่ละลายน้ำทั้งหมด จากผลการทดลองพบว่าผลิตภัณฑ์ที่ใช้เวลาในการให้ความร้อนนาน (20 นาที) มีการเปลี่ยน ของค่าสี ปริมาณฟีนอลิกที่ละลายน้ำทั้งหมด และปริมาณน้ำตาลรีดิวซ์ มากกว่าผลิตภัณฑ์ที่ใช้เวลาในการให้ความร้อนสั้น (16 นาที) ส่วนปริมาณสารแคโรทีนอยด์พบว่าไม่เปลี่ยนแปลงระหว่างการเก็บรักษาทั้ง 3 อุณหภูมิที่ศึกษา ดังนั้นจึงอาจสรุปได้ว่าการเกิดปฏิกิริยาออกซิเดชันของสารประเภทฟีนอลิกและปฏิกิริยาสีน้ำตาลแบบไม่ใช้เอนไซม์เป็นสาเหตุหลักของการเปลี่ยน สีในเมล็ดข้าวโพดหวานบรรจุในภาชนะบรรจุกึ่งอ่อนตัว ซึ่งคาดว่าปฏิกิริยานี้อาจเกิดขึ้นในช่วงแรกของกระบวนการผลิตและเกิดขึ้นอย่างต่อเนื่องด้วยผลของอุณหภูมิในระหว่างการเก็บรักษา นอกจากนี้ยังได้ทำการทดลองเพื่อหาสารต้านการเกิดสีน้ำตาลที่เหมาะสมต่อการยับยั้งการเกิดสีน้ำตาลของผลิตภัณฑ์นี้แต่ยังไม่ประสบผลสำเร็จ

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CHAPTER 1 INTRODUCTION

1.1 Motivation

Sweet corn is one of the important vegetable crops of the world. Corn products are preserved by either canning or freezing. Sweet corn canning is a major vegetable-processing industry (Ghorpade *et al.*, 1998).

The non-metal containers are developed to challenge canned foods and currently gain popularity for fruit and vegetable products as an alternative to the traditional can. Retortable flexible or semi-rigid containers are laminated structures that can be thermally processed like a can, and the product are shelf-stable. Other advantages of retortable carton are reduced heat exposure resulting in improvement in color, flavor and less nutrient losses. This type of container is easy to open. It has low weight and food can be consumed directly from the container.

However, main differences in terms of packaging between metal can and retortable carton are vacuum formation and oxygen barrier property. A metal can is completely air tight and provides oxygen barrier property while the retortable carton, a semi-rigid package consisting of several layers, has problem with oxygen permeation during long-term storage. This has some implications on shelf-life of the products that are sensitive to oxygen.

Thermal treatment is generally applied to extend the shelf- life of fruit products. However, heating processes can affect the quality of product which leads to consumer dissatisfaction. Non-enzymatic browning reactions and pigment destruction have been found to be major causes of such problems. Therefore, kinetic studies are required for prediction of quality degradation resulting from process conditions.

Browning reaction in processed sweet corn can occur or be initiated and enhanced by food handling or processing. Sweet corn in brine packed in flexible and semi-rigid containers turns brown during storage resulting in shelf-life reduction. Non-enzymatic browning is one of the chemical reactions that take place in processed fruit and vegetable resulting in

brown discoloration (Labuza and Baisier, 1992). The reaction also leads to off-flavors, colors degradation, textural changes and loss of nutrients. Brown pigment formation is dependent on many factors such as composition, concentration of samples and storage condition (Nagy *et al.*, 1990). Another possible browning reaction is the autoxidation of phenolic compounds that cause polymerization reaction, which has been shown to cause formation of brown color during thermal processing in other food products such as carrot puree (Riad, 2004). Non-enzymatic autoxidation reaction involves phenolic compounds in food systems leading to undesirable brown oxidation compounds in the absence of polyphenol oxidase. This reaction occurs during processing and storage of processed food (Johannes *et al.*, 1990).

Other deterioration of sweet corn that cause color change is carotenoid degradation. The main cause of carotenoid degradation in foods is oxidation. The mechanism of oxidation in processed foods is complex and depends on many factors. The pigments may be auto-oxidized by reaction with atmospheric oxygen; the reaction rate is dependent on light, heat and the presence of pro- and antioxidants. The degradation of carotenoid increases with the destruction of food cellular structure, increase of surface area or porosity, length and severity of the processing conditions, storage time and temperature, transmission of light and permeability to oxygen of the packaging (Delia, 1999).

This work was aimed to investigate the cause of color degradation of sweet corn kernels in brine packed in semi-rigid containers, and propose the way(s) to overcome. The effect of sterilization time was also investigated.

1.2 Objectives

- 1.2.1 To investigate the cause of color change of sweet corn kernels in brine packed in retortable carton.
- 1.2.2 To study the kinetics of color change of sweet corn kernels in brine packed in retortable carton during storage.
- 1.2.3 To study the effects of anti-browning agents on quality of sweet corn kernels in brine packed in retortable carton.

1.3 Hypothesis

- 1.3.1 Color change occurred in sweet corn kernels in brine packed in semi-rigid containers is caused by phenolic autoxidation, Maillard reaction and carotenoid degradation.
- 1.3.2 Thermal processing affects color change of sweet corn kernels in brine packed in semi-rigid containers
- 1.3.3 Anti-browning agent can inhibit the browning of sweet corn kernels in brine packed in semi-rigid containers

1.4 Scopes of work

- 1.4.1 Study the effects of sterilization times (16 and 20 min at 122°C) on color change of sweet corn kernels in brine packed in semi-rigid container.
- 1.4.2 Study the effects of storage temperatures (30, 40 and 50°C) on color change of sweet corn kernels in brine packed in semi-rigid container.
- 1.4.3 Study the effects of anti-browning agents; (0.01% (w/w) citric acid, 200 ppm ascorbic acid, 200 ppm sodium erythorbate and the mixture of 0.01% (w/w) citric acid and 200 ppm sodium erythorbate) on quality of sweet corn kernels. This part was the continued study from the previous work. The samples were kept at 20, 30, 40 and 50°C and they were taken out for analysis of physicochemical properties every month.

1.5 Expected benefit

The information obtained from this work will be used as a guideline for production of sweet corn kernels in brine packed in semi-rigid containers without browning during storage.

CHAPTER 2 THEORY AND LITERATURE REVIEW

2.1 Sweet corn

Maize (generally used term as “corn products” or *Zea Mays* var. *saccharata*) is one of the five major agricultural exports, viz., rice, cassava, sugar, and rubber, of Thailand. In the last ten-year period, share of maize in country’s total earnings from exports ranged from 8 to 10% (Source: Office of the National Economic and Social Development Board (NESDB),16 December 2002).

Sweet corn is a variety of maize with a high sugar content. Sweet corn is the result of a naturally-occurring recessive mutation in the genes which control conversion of sugar to starch inside the endosperm of the corn kernel (Figure 2.1.). Since the process of maturation involves converting sugar into starch, sweet corn stores poorly and must be eaten fresh, canned, or frozen before the kernels become tough and starchy (Smith *et al.*,1997).

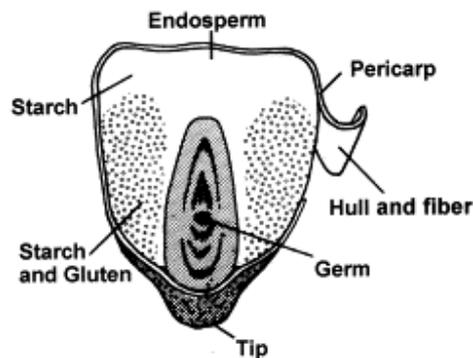


Figure 2.1 Cross-section of corn kernel showing location of major components.

Source: Shukla and Cheryan (2001)

2.2 Packaging for Retorting

2.2.1 Metal Containers

Metal cans are the most common metal containers used for food packaging. The traditional three-piece can (open or sanitary) is still very widely used for heat-processed foods. The

cylindrical can body and two ends are made separately. Cylindrical cans made of tin-plate steel are widely used, although lacquered tin-free steels are gradually replacing them (Holdsworth, 1997 and Brennan, 2006).

2.2.2 Retortable Flexible

Retortable flexible or semirigid containers (Retortable carton) are laminate structures (Figure 2.2) that can be thermally processed like a can, and the product is shelf-stable for a period or up to 24 months. Retortable flexible container, include retort pouches or semirigid containers, are laminate structures that are thermally processed like a can, are shelf-stable. The retortable pouch as a package for heat preserved foods offers potential improvements in convenience and quality by virtue of its shape and composition. Other advantages are reduced heat exposure resulting in improvement in color, flavor and less nutrient losses. In addition superior organoleptic quality of the product can be achieved. This type of container is easy to open. It has low weight and food can be consumed directly from this container. The materials for flexible containers must provide superior barrier properties for a long shelf-life, seal integrity, toughness and puncture resistance, and must also withstand the rigors of thermal processing (Lopez, 1997).

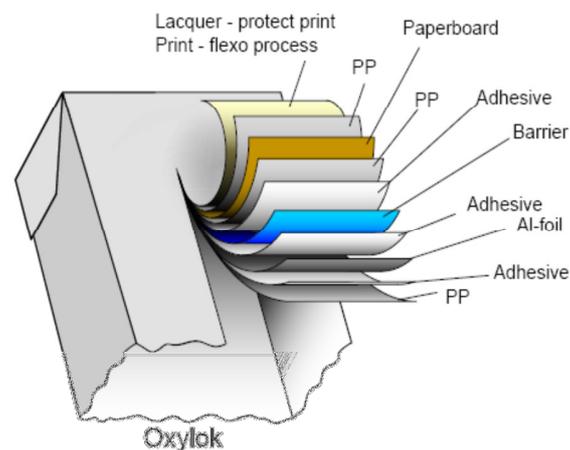


Figure 2.2 Composition of retortable carton

2.3 Browning Reactions

Browning reactions which cause a color change to brown or brownish-black are widespread phenomena which take place during processing and storage. These reactions occur in several food products such as meat, fish, bread, fruit and vegetable. Browning reaction influences the appearance, flavor and nutrients of the food products involved. There are two types of browning that commonly occur in foods (Eskin, 1990). One is caused by enzymatic reaction and the other by non-enzymatic reaction.

2.3.1 Enzymatic Browning Reaction

The enzymatic reaction can occur in food due to the reaction of phenolase or (Hutchings, 1999). The enzymatic browning occurs rapidly when fruits and vegetables are subjected to processing, such as pressing of apples in making cider or peeling and cutting of potatoes. Since enzyme, substrate, and oxygen must all be present for the development of this type of browning, elimination of any one of the three agents will prevent the browning. Ways of preventing this discoloration are heat inactivation of enzyme, the exclusion of oxygen and the selection of varieties poor in substrate content or enzyme activity. Storage at low temperature and the addition of sulfur dioxide, ascorbic acid, citric acid, sodium chloride, or combinations of these compounds will inhibit browning (Markakis, 1992).

2.3.2 Non-enzymatic Browning Reaction

Non-enzymatic browning is one of the most chemical reactions that take place in processed fruit and vegetable. Undergoing non-enzymatic browning usually exhibits a brown discoloration (Labuza and Baisier, 1992). The reaction also leads to off-flavors, colors degradation, textural changes and loss of nutrients. Brown pigment formation, the product from browning reaction, is dependent on many factors such as composition, concentration of samples and storage condition (Nagy *et al.*, 1990).

2.3.2.1 Maillard reaction

The Maillard reaction can contribute to a serious problem during the processing and storage of food products. The reaction occurs between reducing sugars and α -amino groups of amino acids, peptides and proteins (DeMan, 1980). The Maillard reaction involves many

steps. The consequences of Maillard reaction can be described as follows. The initial reaction is the condensation of the carbonyl group of a reducing sugar (aldose) with a free amino group of a protein or an amino acid, which loses a molecule of water to form N-substituted glycosylamine. This is unstable and rearrangement molecules. Next, a degradation of the amino sugars occurred with loss molecule of water to form intermediate compound, HMF. Finally, the intermediate compounds reacted with amino compound and condense molecules to form brown pigment (melanoidin). The Maillard reaction is affected by many factors such as pH, temperature, moisture content and sugar (Eskin, 1990). Hydrolysis of the glycosidic bond in sucrose is facilitated by a low pH and high moisture levels, resulting in increase in the Maillard reaction rate. The rate of Maillard reaction is increased with raising temperature (Eskin, 1990). Carabasa-Giribet and Ibarz-Ribas (2002) studied the kinetics of color 12 development in glucose-amino system at high temperatures (85-100°C). The results showed that 5-hydroxymethylfurfural (HMF), the precursor of Maillard reaction,

Increased with temperature and heating time. Gogus, *et al.* (1998) studied kinetics of Maillard reactions between the major sugars and amino acids of boiled grape juice. They concluded that type of amino acid had a minor effect comparing to type of sugar on the formation of both intermediates and final products of the Maillard reaction. Moreover, temperature was found to be the most important parameter affecting the reaction rate.

2.3.2.2 Phenolic Compounds Autoxidation

Phenolic compounds are widely distributed in the plant kingdom and are therefore present in all plant-derived food systems. The oxidative browning of polyphenols in food system is well-known since this usually undesirable reaction results in a loss of visual and nutritional value in food products. Two types of phenolics browning reactions are involved. Enzymatic oxidation is the more important reaction in fresh fruits and juices, when polyphenol oxidase is present. In processed foods with the enzyme removed or inactivated, substantial nonenzymatic autoxidation can still take place lead to undesirable brown oxidation compounds (Cilliers and Singleton, 1990). These reactions occur during processing or storage.

Autoxidation refers to the formation of cross-linked structures as a result of exposure to light and oxygen. Under the influence of light, oxygen can abstract a proton, thereby generating a radical. This is particularly likely to occur if the proton is contiguous to a double bond because the radical electron can be delocalized, thus lowering the energy. Phenolic compounds are easily autoxidized. The radical that is generated can subsequently react with other radicals to form a dimer, Since the radical electron is delocalized, several structures at the time of the reaction (Vermerris and Nicholson, 2009).

Initial oxidation of compounds results in formation of its quinone. The o-Quinones formed may react further with amino acids or proteins or polymerize. Food processing that includes alkaline treatment leads to rapid phenol oxidation and thus resulting in decreased nutritional value (Cilliers and Singleton, 1989). The same reaction takes place at an appreciable rate under acid conditions especially if metal catalysys are present.

Phenolic polymerization reactions due to autoxidation can result in brown-colored pigments that are detrimental to processed food quality. Browning rates of caffeic acid solutions are pH dependent with yellow pigments formed initially, followed by brown pigments as pH increases (Cilliers and Singleton, 1990). The limiting factor for phenolic autoxidation is the presence and concentration of the phenolate ion, which declines with decreasing pH. The phenolate ion is a highly reactive species that catalyzes oxidative reactions in phenolic acid systems. Acidified phenolic solutions will generally remain colorless unless polymerization occurs directly from molecular oxygen present in the system. Therefore, oxygen exclusion coupled with product pH is important for controlling phenolic polymerization reactions (Bucheli and Robinson, 1994). Moreover, Talcott and Howard (1999) studied the color degradation in processed carrot puree and reported that brown color formation in processed carrot puree can result from Maillard reaction and complexation with o-quinones, which are intermediates in phenolic acid oxidation. Losses of color, total soluble phenolics, total carotenoids, sugar and pH were occurred in O₂-sparged samples as compared to N₂-sparge. Results indicated that phenolic acid condensation was responsible for the yellow and brown pigments formed, with little contribution by Maillard browning at the pH range of strained carrots (pH 5.0-5.5).

2.4 Pigment Destruction

Natural pigments vary in their physical and chemical properties. Many are sensitive to oxidation, pH change, light, processing temperature and duration and heavy metal contamination. Carotenoids can be altered or partially destroyed by acids and are generally stable in bases and water activity changing, sensitive to light exposure, and prone to enzyme attack (Stell *et al.*, 2000).

The capusine yellow or reddish-yellow color of papaya solely depends on the presence of carotenoid content in the fruit. Carotenoids are comprised of 2 structural groups, namely hydrocarbon carotenes and oxygenated xanthophylls. The basic carotenoid structural backbone consists of isoprene units linked covalently to create a symmetrical molecule. The red and/or yellow color of sweet corn is due to the presence of various pigments like lutein, zeaxantine, β -carotene and unresolved mixture of pigments.

The carotenoid structure contains carbon-carbon double bonds (Figure 2.1) which related to the color appearance (yellow-red color). The greater conjugate double bonds present in the molecule, the color will become more red (MacDougall, 2002). Generally, the conjugated double bonds of carotenoid compounds exist in an all-trans configuration. Isomerization reaction from trans- to cis- form results in color changes as shown in Figure 2.2 (MacDougall, 2002). This transformation is induced by thermal treatment, exposure to organic solvents and treatment with acids (Fennema, 1996).

According to the finding of Singleton, *et al.* (1961), carotenoid isomerization in fruit tissue required many hours to reach completion at room temperature, but could be completed within 30 minutes at 100°C

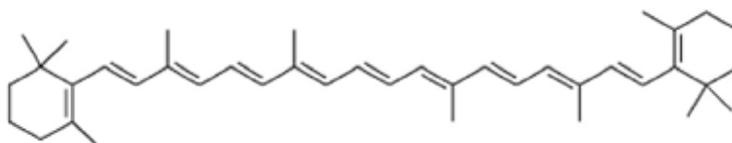


Figure 2.3 Structure of carbon-carbon double bonds in β -carotene

Source: DeMan, (1976)

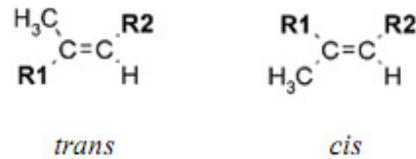


Figure 2.4 Scheme of trans- and cis- double bonds

Source: Schoefs, (2002)

Carotenoids are heat stable in systems with minimum oxygen content. However, high carotenoid foods showed distinct color shift during thermal processing as heat induces cis-trans isomerization reaction (Klavi *et al.*, 1981). Color can be related to carotenoid content and formation of cis carotenoid isomers. Vitamin A content decreased along with increasing temperature and heating time. Moreover, the carotenoid pigments were shown to contain a high proportion of epoxide groups and subsequently isomerized to furanoid forms in contact with acid, hence leading to the loss of yellowness. Maintenance of naturally colored pigments in thermally processed and stored foods has been a major challenge in food processing (Clydesdale *et al.*, 1970; Ihl *et al.*, 1998). Various factors are responsible for the loss of pigment and color during processing of food products. These include nonenzymatic and enzymatic browning and process conditions such as pH, acidity, oxidation, packing material and duration and temperature of storage (Ahmed *et al.*, 2002).

2.5 Color Measurement

Color is an initial attraction for consumers to buy food products. Visual perception of food results from a stimulation of the receptors in the retina by electromagnetic waves in the visible spectrum and the color interpretation is taken place in the brain. However, the visual observation of sample may not give the realistic quality due to: eye fatigue, the unavailability of uniform lighting and a suitable environment for the assessment and poor color memory (Hutching, 1999). Therefore, using an instrument to perform the color measurement in terms of numerical dimensions can overcome such problems. Light reflected from colored object can be divided into three components: value, hue and chroma. Value is a measurement of lightness or darkness, hue refers to the predominant wavelength

reflected which determines what the perceived color is (red, green, yellow, blue, etc.) and chroma presents the intensity strength of the color. The color of an objective can be precisely defined in terms of numerical value for these three components. Another three-dimensional coordinate scale for describing color utilizes the attributes of lightness-darkness, yellowness-blueness, and redness-greenness. These dimensions of color, used in tri-stimulus colorimetry, can be quantified by instruments such as a Hunter Lab color and color-differentiating meter (Potter and Hotchkiss, 1995). Three widely used systems for objectively describing color are Munsell, CIE system and Hunter Lab system (Weaver, 1996). The Munsell system is based on three-color space involving hue, value, and chroma. The hue scale is the kind of color dividing into five primary and five intermediate hues. The value scale is a lightness scale ranging from black to white that is 0 to 10. The chroma scale is a measure of the departure of the color perceived from gray of the same lightness. The CIE color system is trichromatic system based on the mixture of the three primary values which are amber (X), green (Y) and blue (Z). The values are known as chromatic coefficient (x , y and z) is calculated for indicated the quantity of primaries (X , Y , Z). The x and y coordinates can be plotted on a chromaticity diagram and the color of the tasted sample can be located in the color and space. However, the color space of CIE XYZ system is not uniform and improvement had occurred. Then, the CIE L^* , a^* and b^* space known as CIELAB, has generally replaced which has the color space similar to Hunter system. Hunter Lab system is a tricolorimetric system which has tristimulus values: L value (lightness or darkness), a value (redness or greenness) and b value (yellowness or blue) as shown in Figure 2.5. The three values in CIE system can be calculated to Hunter L , a , b using conversion equations. For a particular color, hue or dominant wavelength is given by the ratio a/b or by one of the angles $\theta = \tan^{-1}(b/a)$ or $\theta = \tan^{-1}(a/b)$.

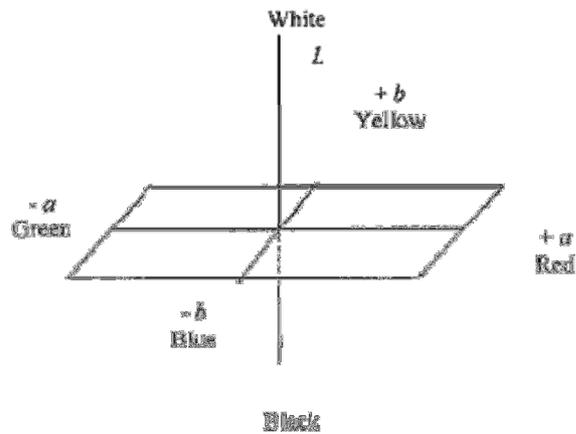


Figure 2.5 The Hunter L, a, b color space

Source: DeMan, (1980)

Hunter values may be used to calculate the total color difference (ΔE) between a sample and a standard. It can be expressed as the coordinates of color space. Hence

$$\Delta E = [(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2]^{1/2} \quad (2.1)$$

As mentioned earlier, the color of product can be used as an indicator for quality control in fruits and fruit products. The Hunter system is more frequently used scale to measure the color of food product. Many previous works have studied the color degradation kinetics of food materials during thermal processing in terms of changes in Hunter tristimulus color values L , a and b (Barreiro, et al., 1997; Lozano and Ibarz, 1997; Avila and Silva, 1999; Garza, et al., 1999).

2.6 Kinetics of Quality Change in Food

There are many factors affecting the change in food material during heat processing such as the color of foods which is occurred from pigment destruction and nonenzymatic browning reaction (Lozano and Ibarz, 1997; Ibarz, et al., 1999; Avila and Silva, 1999). To evaluate the effect of heating on food materials, knowledge of the following information are needed namely; kinetic reaction rate of destruction and dependence of the rate constant on temperature. This section describes the theory of kinetic reaction and the relevant literatures.

2.6.1 Theory of Kinetic Reaction

The colors of foods are easily changed by various reactions during heat treatment. The main reactions are pigment destruction and non-enzymatic browning reaction (Lozano et al., 1997; Ibarz et al., 1999; Avila et al., 1999; Maskan et al., 2002). To optimize the process, it is important to determine the kinetic parameters (reaction order, reaction rate constant and activation energy) for color change. Many researches have investigated the kinetics of color change during thermal processing of various foods. A zero-order reaction behavior and a first-order reaction have been observed for describing nonenzymatic browning, nutrition losses, ascorbic loss and pigment loss in vegetable and fruit products. The general equation describing the quality loss in term of color is

$$-dC/dt = kC^n \quad (2.2)$$

where C is the measured color scale value, or a combination of the color scale values; t is the heating time and k is the reaction rate constant for color degradation and n is the order of the reaction rate with respect to time.

A zero-order reaction is described as

$$-dC/dt = k \quad (2.3)$$

and after integration (for constant reaction rates) yields

$$C - C_0 = k (t-t_0) \quad (2.4)$$

where C_0 = concentration at time zero (t_0). Equation 2.4 indicates that the rate constant can be calculated from the slope of the linear relationship.

A first-order reaction is described as

$$-dC / dt = kC^1 \quad (2.5)$$

And after integration yields

$$C = C_0 \exp [-k(t-t_0)] \quad (2.6)$$

The rate constant can be calculated from the slope obtained from the appropriate linear transformation.

In some case, simple kinetics order could not describe the color degradation of fruit products due to heat treatment (Ibarz, et al., 1999; Garza et al., 1999). Therefore, the combined model (Ibarz, et al., 1999) has been proposed as follows. The degradation of reaction is based on the two stage mechanism. The first stage is color formation from the Maillard reaction, which follows a zero order kinetics and the second is pigment destruction follows first order kinetics. These can be written as;

Sugars + Amino acids \longrightarrow Colored polymers (zero order reaction, k_0)

Pigments \longrightarrow Non color products (first order reaction, k_1)

If C is the variable measuring the color, let

$$dC/dt = k_0 - k_1C \quad (2.7)$$

The equation can be integrated with limited conditions for initial time, at $t = 0$, the color $C = C_0$ obtaining

$$C = K_c - (K_c - C_0)\exp(-k_1t) \quad (2.8)$$

where

$$K_c = k_0/k_1$$

Equation (2.8) can be rearranged to represents to fractional conversion, obtaining

$$(C - K_c)/(C_0 - K_c) = \exp(-k_1t) \quad (2.9)$$

Equation (2.8) can describe the total color difference (ΔE). To obtain this value, the color C parameter is substituted by ΔE and the difference of the color at initial time was zero and then Equation (2.8) changes to:

$$\Delta E = K_c (1 - \exp(-k_1t)) \quad (2.10)$$

Many studies applied the fractional conversion to explain the quality loss in their works. Nourian, et al. (2003) studied the kinetic changes in cooking quality of potatoes stored at different temperatures. They used modified first order equation to characterize the kinetics of color change L and ΔE of cooked potatoes that fitted better than simple model. Chen and

Ramaswamy (2002) studied the color and texture change kinetics in ripening bananas. They implied that the color change (L , b and ΔE) of ripen bananas were good described by fractional conversion (Chen and Ramaswamy, 2002). In the work of Ibarz, et al. (1999), the kinetic model was used to describe the effect of thermal treatment in pear puree. A first order was applied to L^* changes while absorbance at 420 nm was described by a zero kinetic and auto-catalytic was applied for HMF content.

2.6.2 Temperature Effect on Chemical Reaction Rate

It has been known that temperature has marked effect on the quality of food products. If the rate constant is high, this means the significant change in food appearance and nutrient loss. To describe the effect of temperature on the food quality, Arrhenius equation which is the most common valid tool is applied and the equation is as follows:

$$k = K_0 \exp(-E_a/RT) \quad (2.11)$$

Taking logarithms of the above equation gives;

$$\ln k = \ln K_0 - E_a/RT \quad (2.12)$$

K_0 and E_a can be determined from linear regression analysis of $1/T$ and $\ln k$.

Where k = The rate constant

K_0 = The frequency factor

E_a = The activation energy (kJ/mol K)

R = Ideal gas constant (8.314 kJ/mol K)

T = The absolute temperature (K)

Several researchers have published works on modeling of thermal degradation kinetic of brown color development of fruit products (Beveridge and Harrison, 1984; Nagy, et al., 1990; Lozano and Ibarz, 1997; Garza, et al., 1999; Avila and Silva, 1999; Ibarz, et al., 1999). These studies were used the Arrhenius model to describe the temperature dependence of the reaction rate constant for the parameter in the studies. Lozano and Ibarz (1997) studied the color changes in concentrated apple, peach and plum pulp during heating at 56, 66, 80 and 94 °C for 700 minutes. They indicated that the decrease in L values followed

apparent first order reaction kinetics through the 20 heating period. Total color difference (ΔE) was fitted with a combined model. This could be explained that more than one mechanism contributed to color deterioration. The different values of activation energy (E_a) were found for each type of fruit.

CHARTER 3 MATERIALS AND METHODS

This chapter describes the materials, apparatus, reagents and methods used in this research.

3.1 Material

Sweet corn (*Zea mays var. rugosa*) of ATS5 variety, used in this study was obtained from the suppliers of Siam Del Monte Co., Ltd.

3.2 Experimental Procedures

The cause of pigment degradation of sweet corn in brine when it is packed in flexible or semi-rigid container instead of can was investigated. The experiment was divided into 2 parts. The first part was concerned with the effects of sterilization time on product qualities as indicated by the change in color ($L^*a^*b^*$ values), amount of oxygen in the headspace, dissolved oxygen, reducing sugar, total carotenoid content and total soluble phenolic content. The second part involved the effects of storage temperatures on the product qualities in terms of color, browning index, reducing sugar, total carotenoid content and total soluble phenolic content.

3.2.1 Production Process

The ear of sweet corns were sent to the Wilter to soften the peel by using steam at 90°C and the husk and silk were removed by the husker. The kernels were then cut from the cob. All unacceptable particles were removed from the sweet corn kernels by the scalper reel, the flotation cleaner and the air blower, respectively. After grading, the sweet corn kernels were sent to the metal detector. The sweet corn kernels were filled into the retortable carton and covered with the packing medium containing 1.2% brine and 2% sugar. The temperature of packing medium was about 85-95 °C. The oxygen was removed from the filled containers in the exhausting step with the use of steam flow and nitrogen flushing before sealing the container and the products were sent to the retort. The thermal process applied was 122°C for 16 and 20 minutes with the overpressure of 4 bars.

3.2.2 Study on the effects of sterilization time and storage temperature on product quality

For studying the effect of sterilization time on pigment degradation, two treatments were performed, first was sterilization at 122°C for 16 minutes and second sterilization at 122°C for 20 minutes. The products obtained were then stored at 30, 40 and 50°C for 12 weeks and were periodically taken out for analysis of physicochemical attributes. Color (CIE $L^*a^*b^*$), oxygen content in the headspace, dissolved oxygen, reducing sugar, browning index, total carotenoid content and total soluble phenolic content were determined to indicate the product qualities. Each analysis was performed in duplicate with separate package.

3.2.3 Study of the effects of anti-browning agents on product quality

The antibrowning agents used for inhibiting browning reaction in sweet corn kernels in brine consisted of 200 ppm ascorbic acid, 200 ppm sodium erythorbate, 0.01 % (w/w) citric acid, and the mixture of 200 ppm sodium erythorbate and 0.01% (w/w) citric acid with different sterilization values of $F_0 = 6$ and 8 minutes and storage at 30 and 40°C. The parameters investigated to follow the non-enzymatic browning reaction of sweet corn kernels in brine during storage were color (CIE $L^*a^*b^*$ values), amount of oxygen in the headspace, dissolved oxygen, total soluble phenolics content, browning index (BI) and 2,5-dimethyl-4-hydroxy-3[2H]-furanone (DMHF) content.

3.3 Apparatus and Reagents

3.3.1 Equipment

1. UV-VIS Scanning Spectrophotometer, Shimadzu Model UV-2101 PC, Kyoto, Japan
2. Water bath, Memmert Model W 600, Schwabach, Germany
3. Color measurement spectrophotometer, Hunterlab Model Color Quest® XE, Virginia, USA.
4. Digital balance, Sartorius Model RC 250S, Göttingen, Germany

5. Refrigerated centrifuge, Hitachi Model Himac CR21, Ibaragi, Japan
6. Blender, Waring, Model 32BL80, New Hartford, CT, USA.
7. pH meter , Schott Gerate CG 841, Mainz, Germany
8. Volumetric flasks
9. Auto pipettes
10. Beakers
11. Separation funnel
12. Cylinders
13. Hot plate
14. High-performance liquid chromatography (HPLC) system, Waters, Milford, MA, USA. consisting of
 - Waters 600 pump
 - Waters 717 auto sampler
 - Water 410 differential refractometer
 - Water 486 tunable absorbance detector
15. Buchner funnel, Side-arm Erlenmeyer flask and Vacuum pulp
16. Filter paper, Whatman No.1,2
17. Nylon membrane 0.45 μm
18. Syringe filter 0.2 μm
19. RP18 column (size 150 \times 3.9 mm, 5 μm particle size)
20. Security guard cartridge
21. Gas Chromatograph, Hewlett Packard Model 5890 series II plus, CA, USA
22. Gas Tight Syringe Interchangeable Needle 1.0 ml, Exmire Ito. Corp Model EXMSGAN100, Fuji, Japan
23. Dissolved oxygen meter, HACH Model SensION6, Colorado, USA.

3.3.2 Chemical Reagents

1. 2,5-dimethyl-4-hydroxy-3[2H]-furanone 95%, Aldrich, Missouri, Germany
2. Ethyl alcohol 95%, AR Grade, Sigma, Germany
3. Methanol alcohol 95%, AR Grade, Sigma, Germany
4. Sodium acetate, AR Grade, Merck, Germany

5. Sodium carbonate, AR Grade, Merck, Germany
6. Hydrochloric acid, AR Grade, Merck, Germany
7. Folin-ciocalteu reagent, Carlo Erba, Italy
8. Methanol HPLC grade , Lab Scan Ltd, Thailand
9. Acetonitrile HPLC grade , Lab Scan Ltd, Thailand
10. Water HPLC grade , Lab Scan Ltd, Thailand
11. DI water
12. Acetone, AR grade , Lab Scan Ltd, Thailand
13. Petroleum ether, AR grade , Lab Scan Ltd, Thailand

3.4 Determination of Product Qualities

3.4.1 Oxygen measurement

Headspace oxygen content was analyzed using HP 5890 gas chromatograph (Hewlett-Packard, Palo Alto, CA, USA) equipped with a HP GC-MS5D column. A 6 ml gas was withdrawn for analysis by drawing a headspace gas sample by piercing a syringe needle through a rubber septum glued on the surface of package. For each analysis a new package was used. Dissolved oxygen in packing medium of product was analyzed using dissolved oxygen meter (HACH, Colorado, USA). The packages were opened and the oxygen probe was immediately inserted into the brine (packing medium of products).

3.4.2 Color measurement

The visual color change of sweet corn was evaluated by measuring their reflectance spectra using a color measurement spectrophotometer (Hunterlab, model Color Quest® XE, USA). The measurement was set up under D65 (day-light) light source, large viewing area (1 inch diameter) and the observer at 10°. The CIE*Lab* parameters, namely “*L**” (lightness; white, 100: black, 0), “*a**” (redness; red, +: green, -) and “*b**” (yellowness; yellow, +: blue, -) were determined by means of the Universal software. The colorimetric spectrophotometer was standardized against a standard white tile (X=80.31 Y=85.1, Z=88.97) on RSIN mode before measuring the sample. The sweet corn kernels were blended to obtain homogeneous samples and then filled in the Petri dish for color measurement. Two readings were obtained for each replication to obtain uniform color value.

3.4.3 Determination of non-enzymatic browning index (BI)

The method as mentioned in Cohen, *et al.* (1998) with some modification was used in the browning index evolution assay; the sweet corn kernels were blended. Ten ml of 95% ethyl alcohol was added to 10 g of blended sweet corn. The mixture was centrifuged at 1,000×g for 15 minutes. The supernatant was filtered with filter paper (Whatman No.1) and then its absorbance was measured at 420 nm by using Spectrophotometer (Shimadzu Model UV-2101 PC, Kyoto, Japan). The absorbance value was considered as the browning index (BI).

3.4.4 Determination of reducing sugar

The reducing sugar was determined using Somogyi-Nelson method as follows; 1 mL of sample solution was added into the test tube. Then add 1 mL of Somogyi and boil the mixture for 15 minutes the red precipitate was obtained. Cool the mixture and, add 1 mL Nelson solution into the mixture and mix. Add 4 mL of distilled water and mix. The mixture was read in a spectrophotometer at 520 nm (A_{520}). Standard curve was arranged using glucose at 20, 40, 60 80 and 100 µg/ mL. Using distilled water as a blank and followed the method as described. The glucose content of the samples was determined from the standard curve of glucose and calculated using the following equation:

$$\text{Glucose content (mg)} = \left(\frac{\text{Absorbance at 520 nm} \times \text{volume of glucose solution}}{\text{Slope}} \right)$$

3.4.5 Determination of total soluble phenolics content

The Folin-Ciocalteu assay was used to measure total soluble phenolics content in sweet corn and expressed as gallic acid equivalents. In this experiment, 15 g of sweet corn kernels were blended in 85 ml of 95% ethanol for 1-2 min then heated for 20 min at 85 °C. Then the sample's extract was stored at -20 °C overnight. The samples were then filtered through filter paper in a Buchner funnel attached to a side-arm Erlenmeyer flask. A vacuum pump was connected to the side arm to speed up the extraction. For determining total soluble phenolics content in the sample, 0.5 mL of the ethanol extract was added to a 20 mL - test tube and 0.5 mL of 0.25N Folin -Ciocalteu phenol reagent was added, the tube was then vortexed and left to stand for 3 min. Next, 0.5 mL of 1N sodium carbonate was added and

the samples were left to stand for 7 min before addition of 3.5 mL DI-water. Lastly, the samples were mixed and left to stand for 30 min before measuring. After 30 min, the sample tubes were then centrifuged at 5000×g for 5 min. The absorbance at 726 nm was then measured using a spectrophotometer (Riad, 2004). Gallic acid was used as a standard, and the soluble phenolic content was expressed as milligrams of gallic acid per kg of sample.

3.4.5 Determination of total carotenoid content

Total carotenoids were determined by soaking 5g sample in 20 mL of AR grade acetone (Lab Scan Ltd, Thailand) for 2 h at room temperature under dark condition in order to get complete carotene extraction. The carotene layer was separated using petroleum ether through separating funnel. The volume was made up to 50 mL with petroleum ether and then this layer was again passed through sodium sulfate over the funnel in order to remove any moisture from the layer. The optical density of the layer was measured at 452 nm using petroleum ether as a blank (Ranganna, 1999). The total carotenoids were calculated using the following formula

$$\text{Total carotenoids (mg/100 g)} = \frac{3.856 \times \text{Optical density of the sample} \times \text{Volume made up} \times 100}{\text{Weight of sample} \times 1000}$$

3.4.6 Determination of 2, 5-dimethyl-4-hydroxy-3[2H]-furanone (DMHF)

The following assay was modified method of Walsh *et al.* (1997). DMHF was extracted by blending 10 g sample of processed sweet corn with 25 ml of methanol acidified with HCl (1000:1) for 1 min. The homogenate was then centrifuged at 2500×g for 5 min at 18°C, filtered, and analyzed by HPLC. Separations were achieved using a Symmetry Shield RP18, 3.9 mm, 15 cm column packed with 5 µm. The mobile phase consisted of methanol (A), acetonitrile (B), and aqueous 0.05 M sodium acetate/acetic acid, pH 4.0 (C). Flow rate was 0.8 mL/min, and sample injection volume was 20 mL. The following linear chromatographic gradients were used: 0 min, 10% A, 5% B, 85% C; 16 min, 20% A, 33% B, 47% C; 28 min, 0% A, 95% B, 5% C. The column was washed with 100% acetonitrile followed by a 2 min linear gradient to re-establish initial conditions. A wavelength UV detector set at 292 nm was used for quantification.

CHAPTER 4 RESULTS AND DISCUSSION

This chapter presents the results and discussion of the study of color degradation kinetics of sweet corn in brine packed in retortable carton during storage as affected by different sterilization times at 122°C. A series of investigation were carried out on oxygen in the headspace, dissolved oxygen, reducing sugar, total carotenoid content and total soluble phenolic content. The samples were sterilized for 16 and 20 minutes at 122°C. The samples were then stored at 30, 40 and 50°C for 12 weeks and the samples were periodically taken out for analysis of physicochemical attributes. Each analysis was performed in duplicate with separated package.

4.1 Study of the effect of storage temperature on product quality

4.1.1 Effect of oxygen on product quality

Oxygen in the product is one of many factors which have an influence on color change of foods. This is because oxidation of carotenoid and phenolic autooxidation can occur directly from molecular oxygen present in the system (Talcott and Howard, 1999; Cilliers and Singleton, 1991).

The headspace oxygen and dissolved oxygen were analyzed using gas chromatograph and dissolved oxygen meter, respectively. Each analysis was performed with separate sample package. Figures 4.1-4.3 show the changes in oxygen in the headspace of product during storage at temperatures of 30, 40 and 50°C while Figures 4.4-4.6 show the changes in dissolved oxygen in the packing medium during storage at temperatures of 30, 40 and 50°C. There was no clear trend among different sterilization times studied when compared with the initial value.

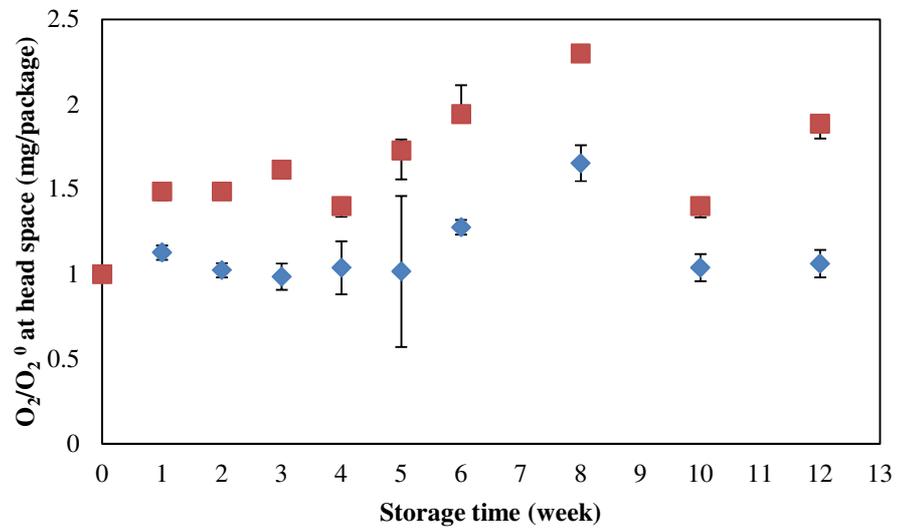


Figure 4.1 Head-space oxygen of sweet corn kernel sterilized for 16(♦), and 20(■) minutes at 122 °C during storage at 30 °C

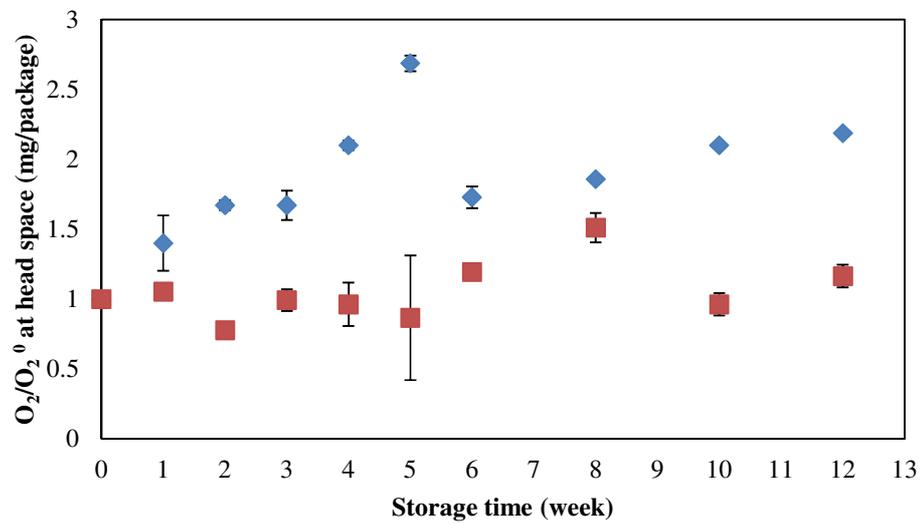


Figure 4.2 Head-space oxygen of sweet corn kernel sterilized for 16(♦), and 20(■) minutes at 122 °C during storage at 40 °C

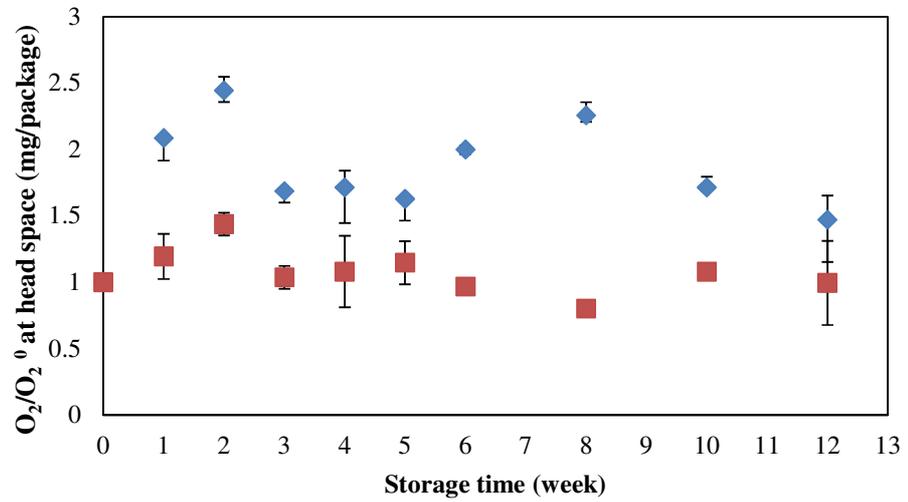


Figure 4.3 Head- space oxygen of sweet corn kernel sterilized for 16(◆), and 20(■) minutes at 122 °C during storage at 50°C

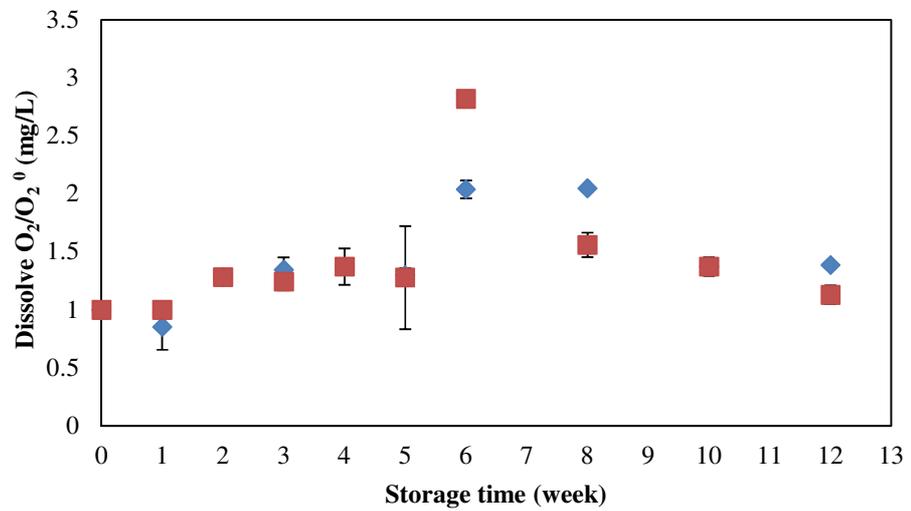


Figure 4.4 Dissolved oxygen content of sweet corn kernel sterilized for 16(◆), and 20(■) minutes at 122 °C during storage at 30°C

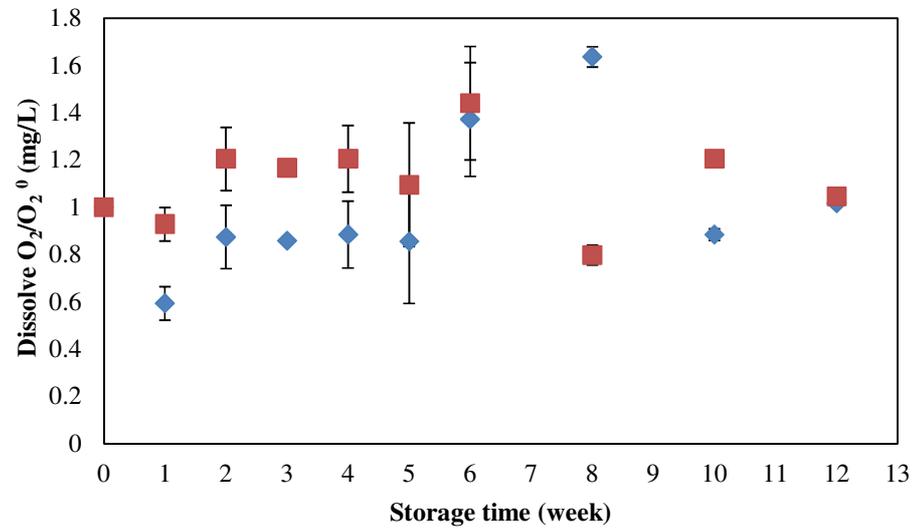


Figure 4.5 Dissolved oxygen content of sweet corn kernel sterilized for 16(◆), and 20(■) minutes at 122 °C during storage at 40°C

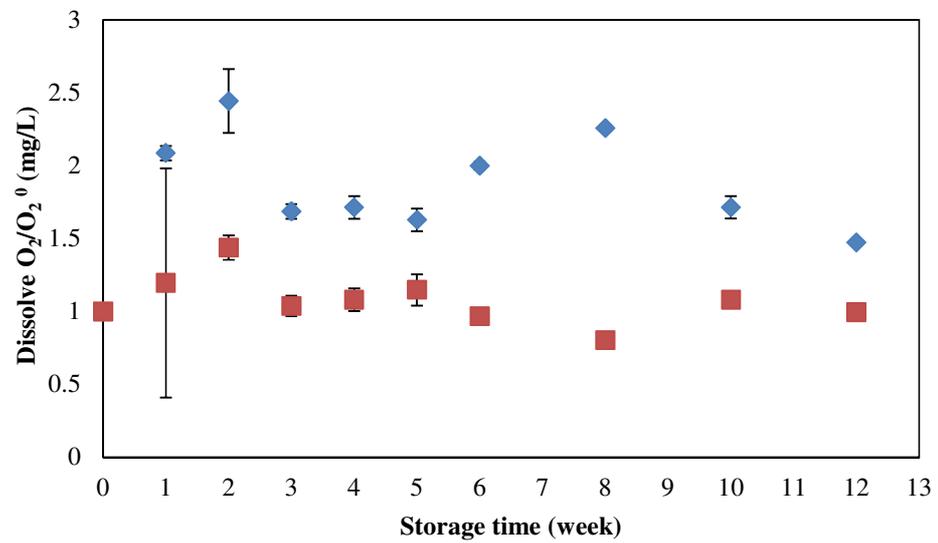


Figure 4.6 Dissolved oxygen content of sweet corn kernel sterilized for 16(◆), and 20(■) minutes at 122 °C during storage at 50°C

4.1.2 Browning Index (BI) of sweet corn kernels

Storage temperature affected browning index (BI) of sweet corn kernels during storage. Browning index is the measurement of changing in absorbance at 420 nm as an index of brown pigment formation from nonenzymatic browning reaction (Koca, 2003). Increasing storage temperature as well as storage time increased browning rate of sweet corn kernels (Figures 4.7-4.9), particularly at storage temperature of 50°C.

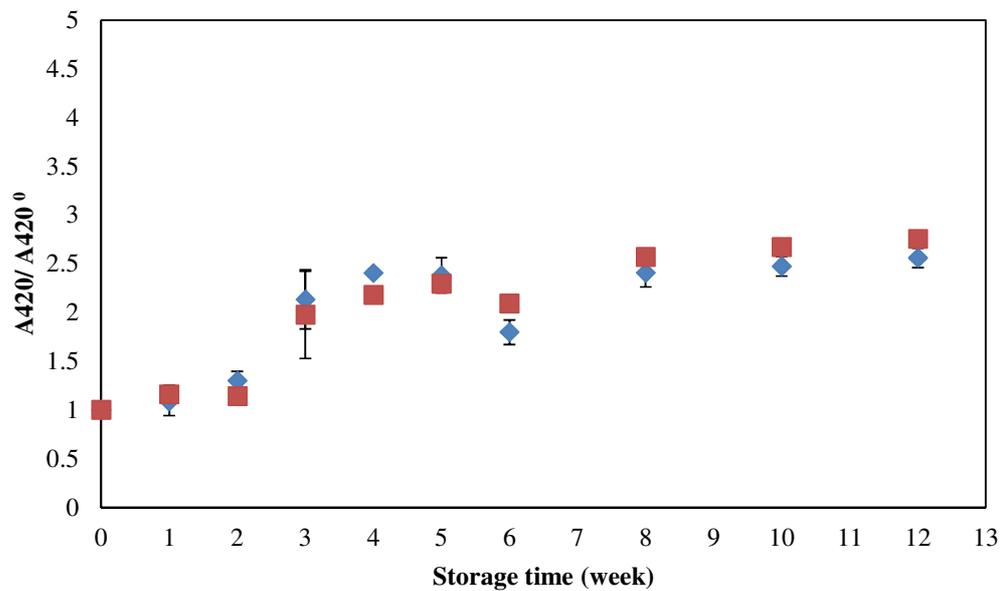


Figure 4.7 Browning Index (BI) of sweet corn kernels sterilized for 16(♦), and 20(■) minutes at 122 °C during storage at 30°C

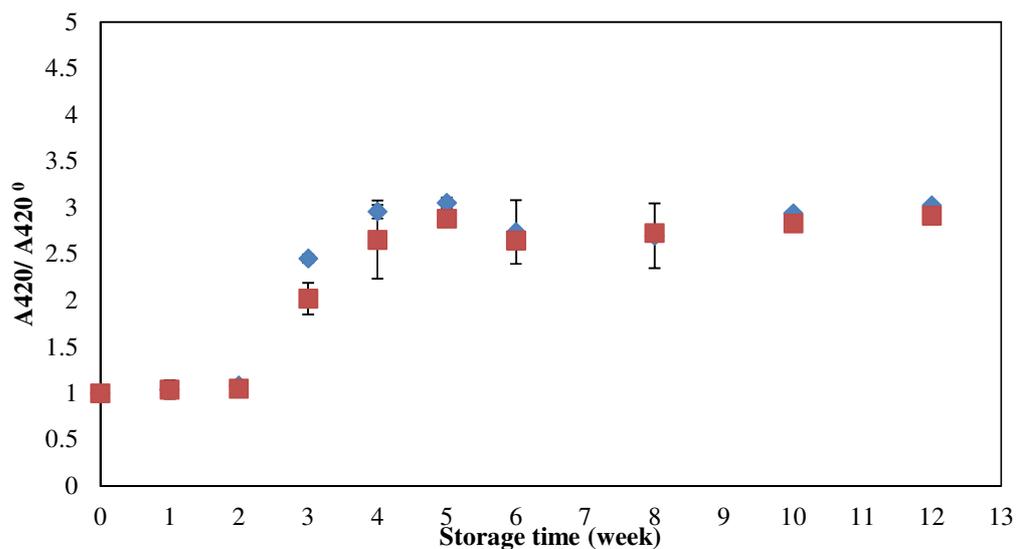


Figure 4.8 Browning Index (BI) of sweet corn kernels sterilized for 16(♦), and 20(■) minutes at 122 °C during storage at 40°C

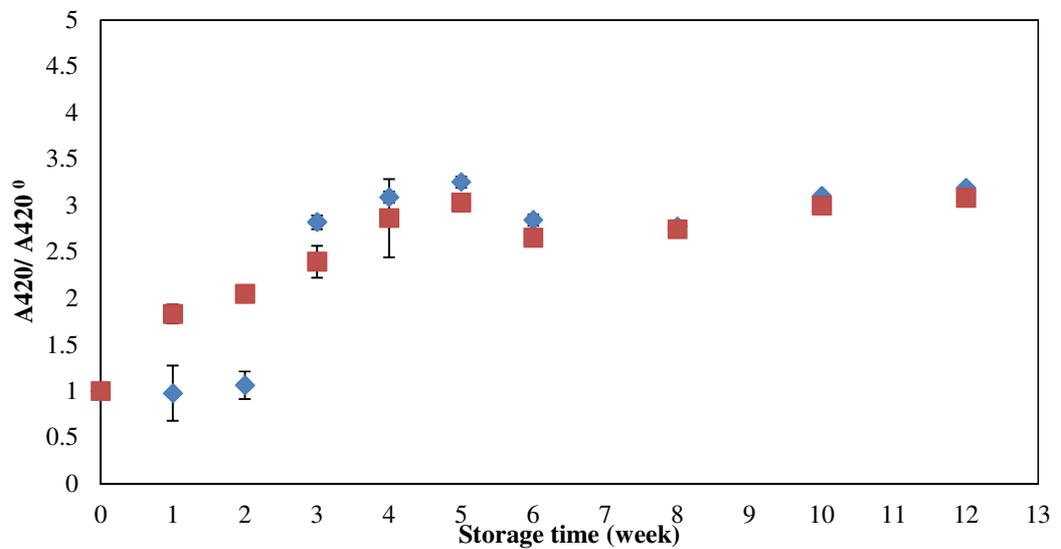


Figure 4.9 Browning Index (BI) of sweet corn kernels sterilized for 16(♦), and 20(■) minutes at 122 °C during storage at 50°C

4.1.3 Total carotenoid content of sweet corn kernels

Carotenoid content of sweet corn kernels was investigated during storage. The initial carotenoid content of the products which were sterilized at 122 °C for 16 and 20 minutes were 640.40 and 695.04 µg/kg, respectively. From Figures 4.10-4.11, the carotenoid content showed quite fluctuated results and no significant difference between samples with different sterilization times was observed. This is because carotenoids are stable in the systems with minimum oxygen content (Ekkalux, 2006) However, it was slightly decreased in samples kept at storage temperatures of 40 and 50 after 8 weeks.

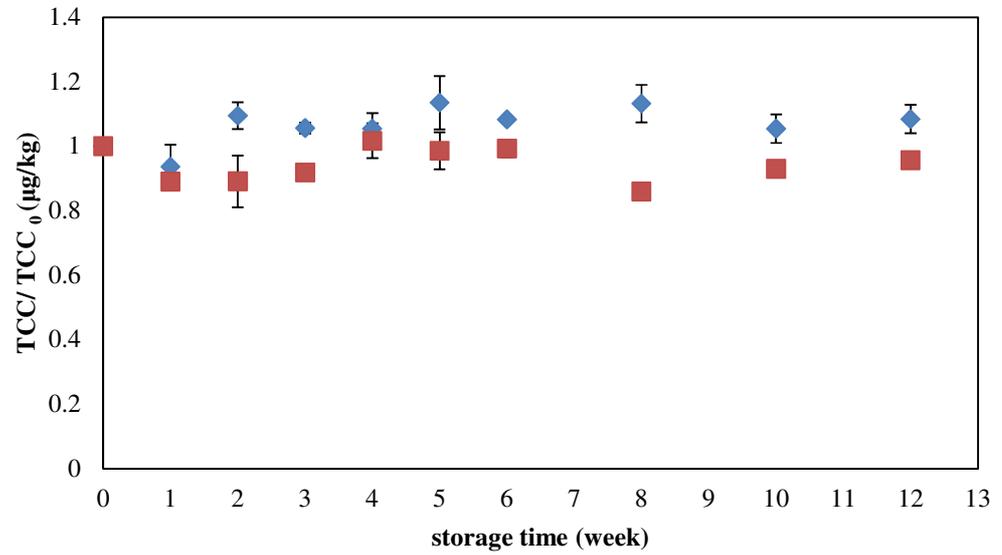


Figure 4.10 Total carotenoid content of sweet corn kernels sterilized for 16(◆), and 20(■) minutes at 122 °C during storage at 30°C

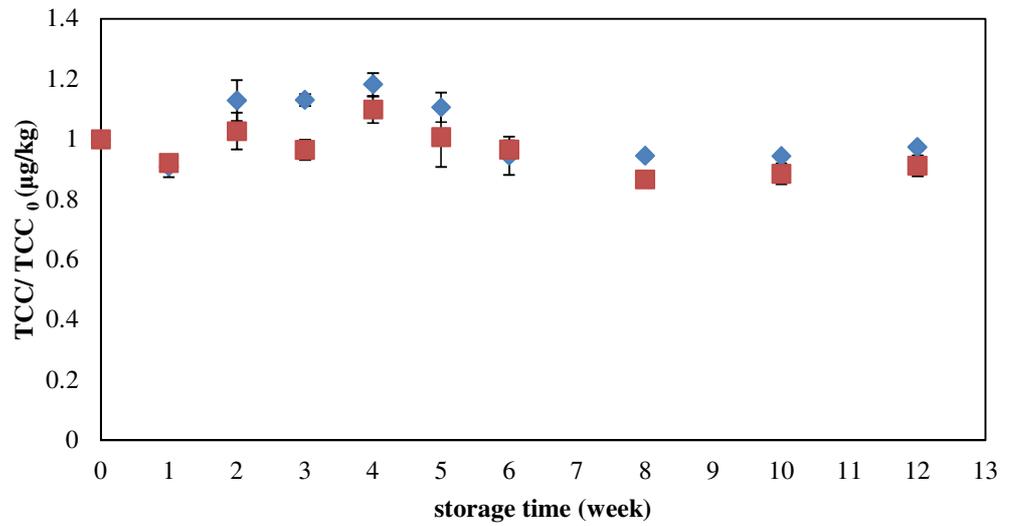


Figure 4.11 Total carotenoid content of sweet corn kernels sterilized for 16(◆), and 20(■) minutes at 122 °C during storage at 40°C

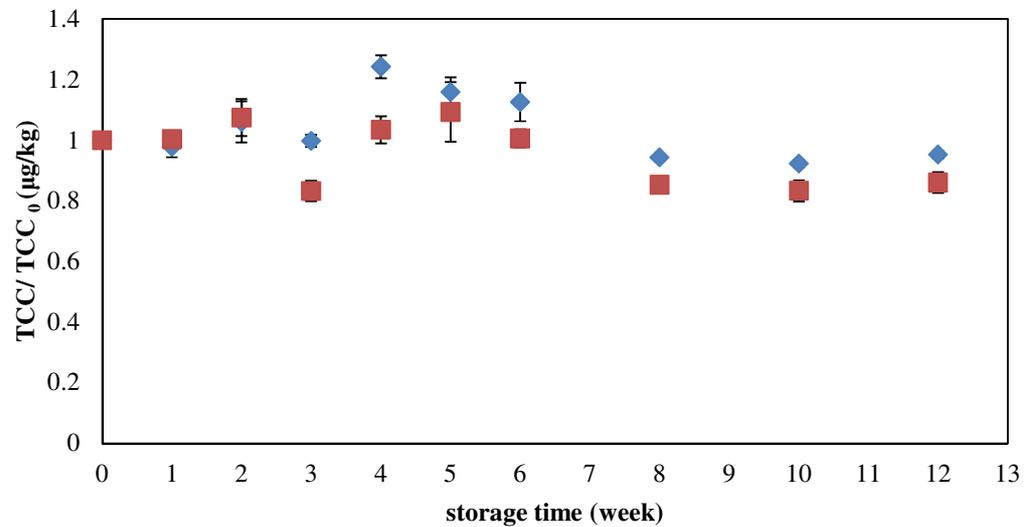


Figure 4.12 Total carotenoid content of sweet corn kernels sterilized for 16(◆), and 20(■) minutes at 122 °C during storage at 50°C

4.1.4 Reducing sugar content of sweet corn kernels

The Maillard reaction can contribute to a serious problem during the processing and storage of food products. The reaction occurs between reducing sugars and α -amino groups of amino acids, peptides and proteins (DeMan, 1980).

Figures 4.13-4.15 show an evolution of reducing sugar content of sweet corn kernels of 2 different sterilization times during storage. No significant differences were found in the reducing sugar content of sweet corn kernels between 2 sterilization times studied, however it was rapidly decreased in samples kept at all storage temperatures after 2 week-storage and seemed to be constant after storage for 8 weeks.

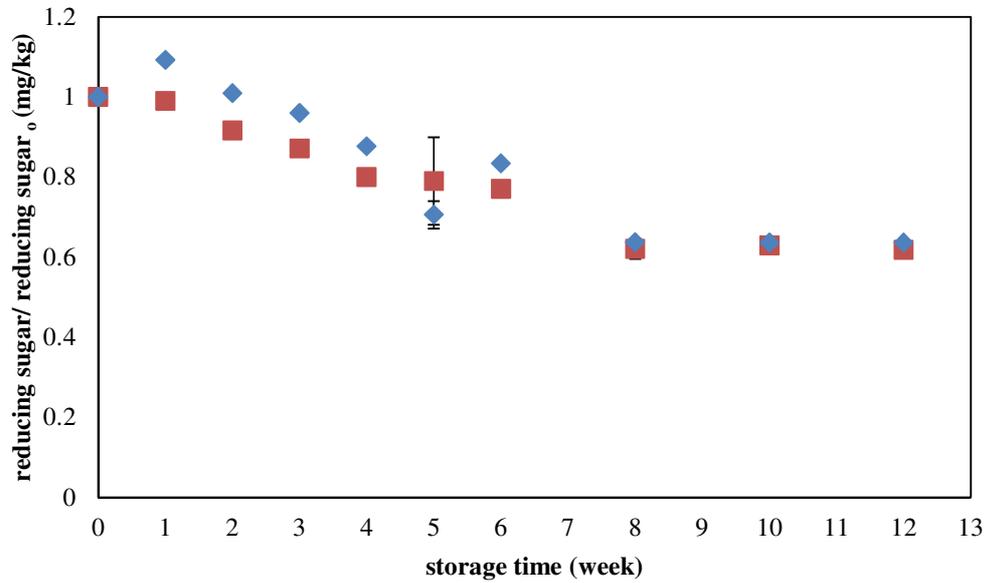


Figure 4.13 Reducing sugar content of sweet corn kernels sterilized for 16(◆), and 20(■) minutes at 122 °C during storage at 30°C

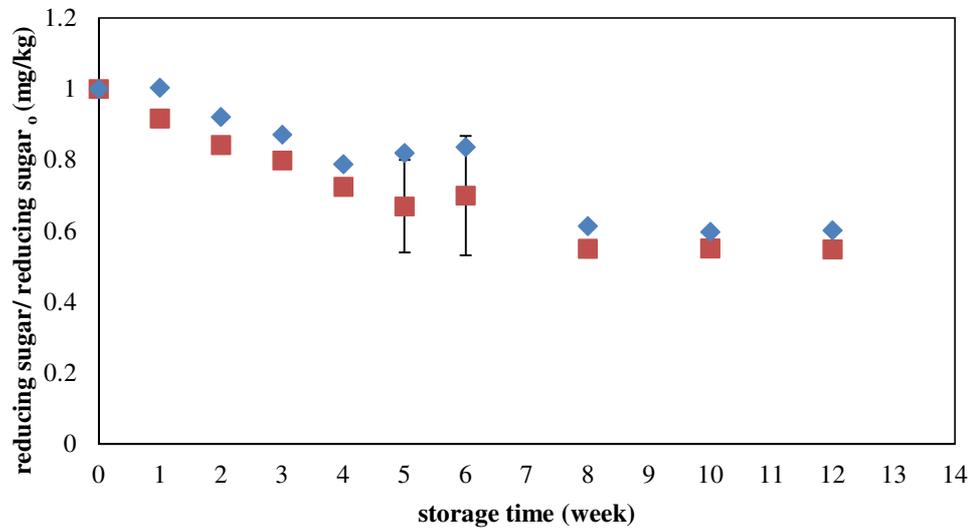


Figure 4.14 Reducing sugar content of sweet corn kernels sterilized for 16(◆), and 20(■) minutes at 122 °C during storage at 40°C

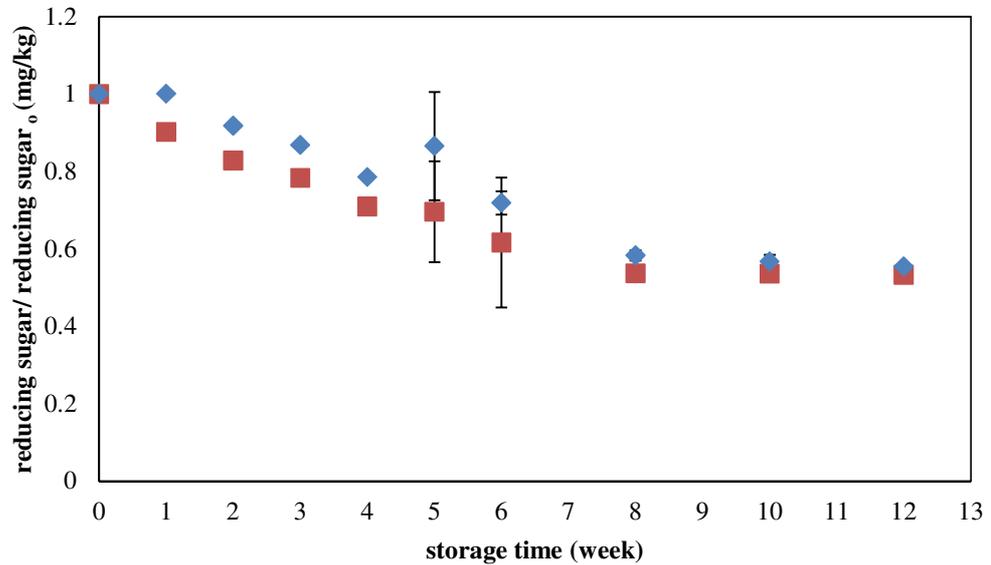


Figure 4.15 Reducing sugar content of sweet corn kernels sterilized for 16(◆), and 20(■) minutes at 122 °C during storage at 50°C

4.1.5 CIE color characteristics of sweet corn kernels

For color measurement, the product was blended to obtain homogeneous sample which was then measured using a HunterLab color measurement spectrophotometer. Readings were obtained in CIE (L^* , a^* , b^*) color system. Figures 4.16-4.18 show changes in L^* value or lightness of the blended sweet corn kernels as affected by two different sterilization times (16 and 20 minutes at 122 °C). At storage temperatures of 30 and 40°C, the samples sterilized at both times showed no significant differences in their lightness. For the storage temperature of 50°C, the samples which were sterilized for 20 minutes showed slightly lower L^* value than those sterilized at 16 minutes. For the sample's redness represented by a^* value as shown in Figures 4.19-4.21, it was found that a^* values of the samples stored at high temperature rapidly increased at both sterilization times. Besides the b^* value (yellowness) was rapidly decreased in the first storage week and then slowly decreased with quite fluctuated results as shown in Figures 4.22-4.24. It was observed that all color values indicated darkening of the product with increased storage time as well as storage temperature.

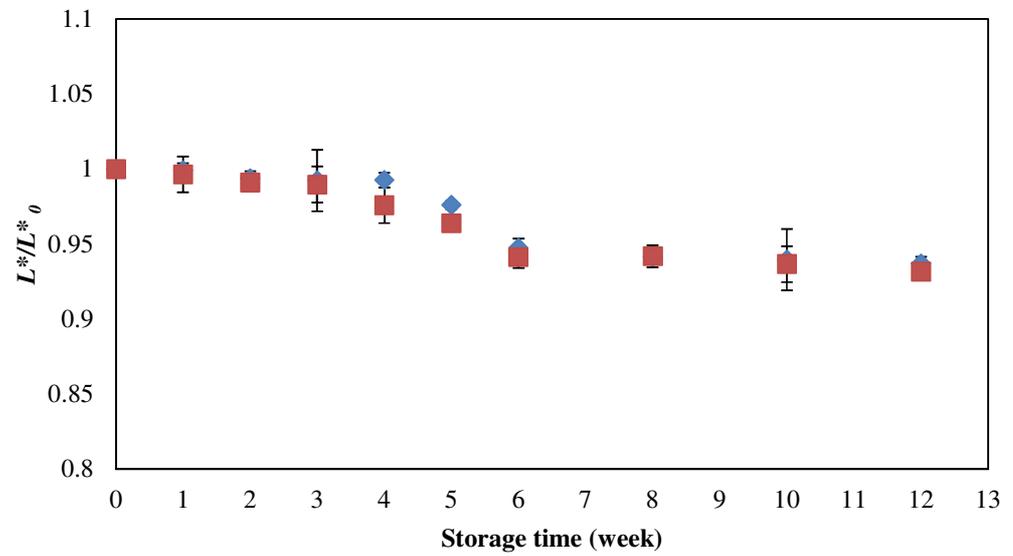


Figure 4.16 L^* value of sweet corn kernels sterilized for 16(♦), and 20(■) minutes at 122 °C during storage at 30°C

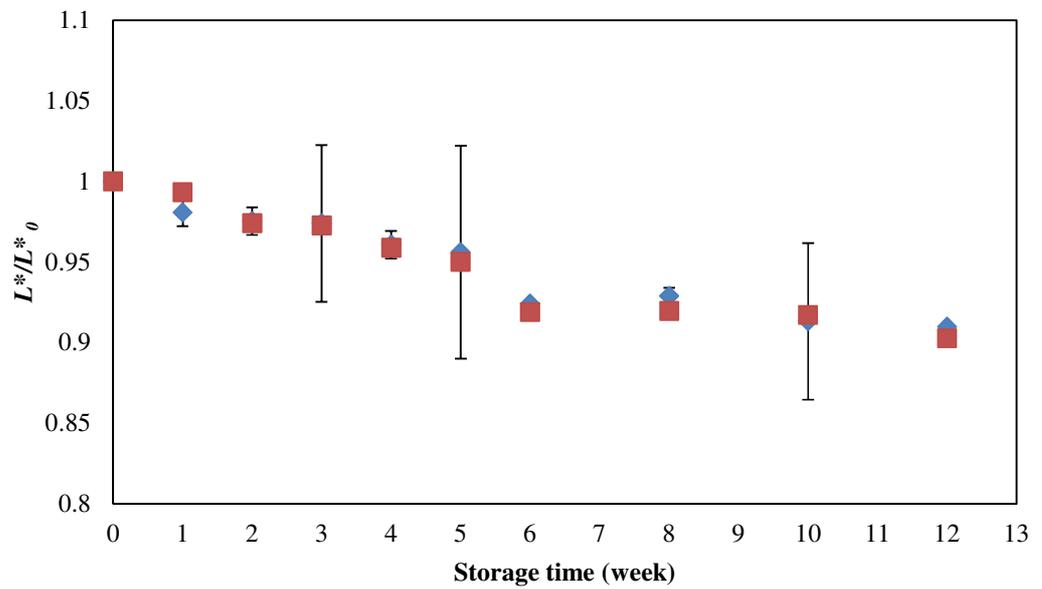


Figure 4.17 L^* value of sweet corn kernels sterilized for 16(♦), and 20(■) minutes at 122 °C during storage at 40°C

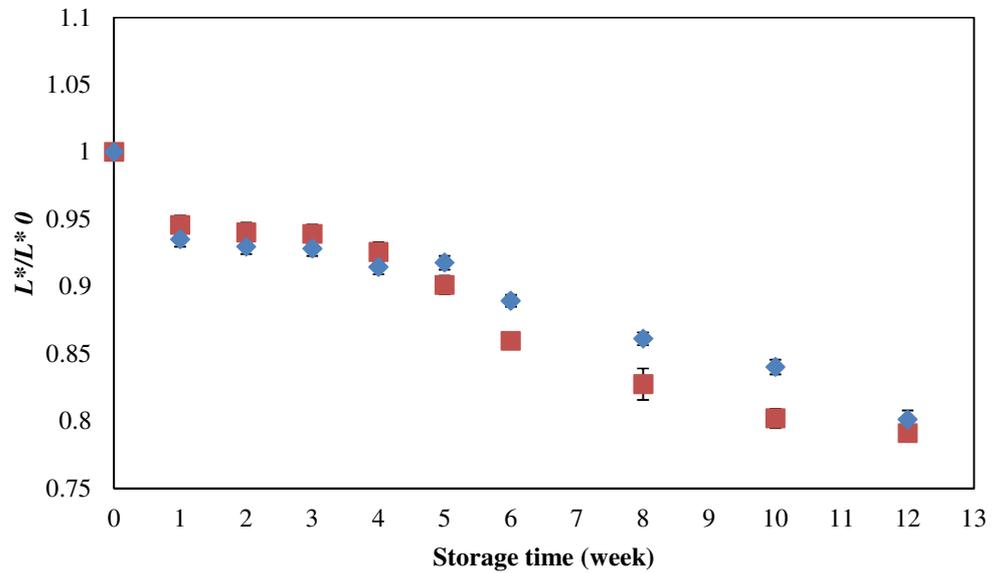


Figure 4.18 L^* value of sweet corn kernels sterilized for 16(♦), and 20(■) minutes at 122 °C during storage at 50°C

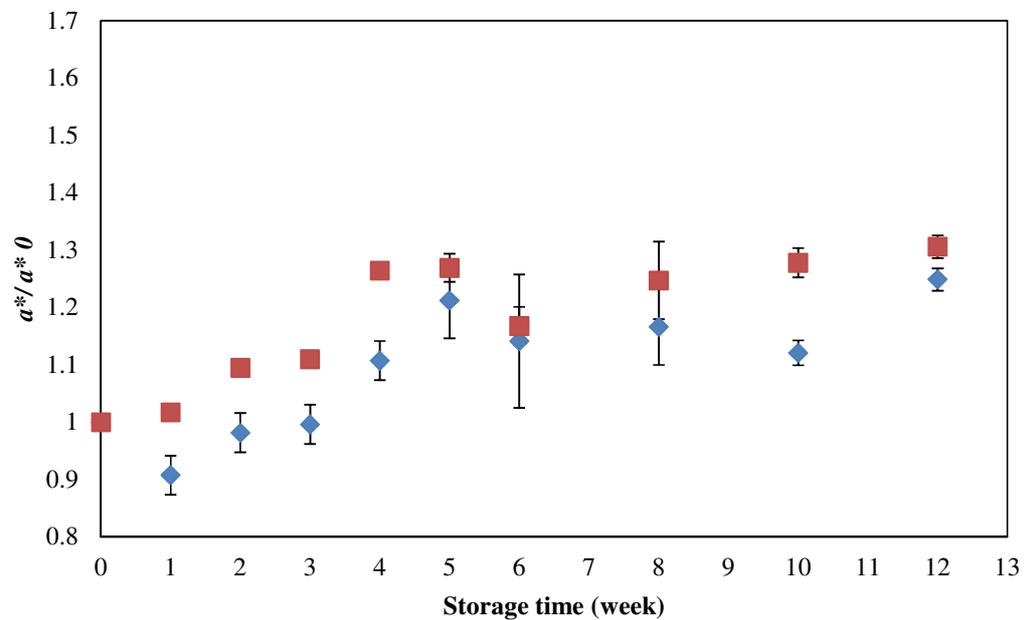


Figure 4.19 a^* value of sweet corn kernels sterilized for 16(♦), and 20(■) minutes at 122 °C during storage at 30°C

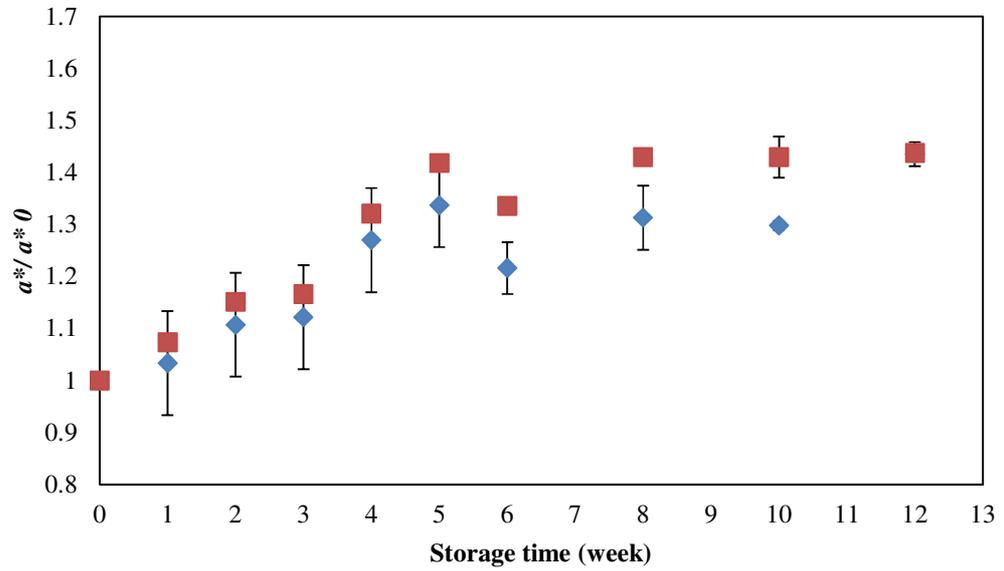


Figure 4.20 a^* value of sweet corn kernels sterilized for 16(♦), and 20(■) minutes at 122 °C during storage at 40°C

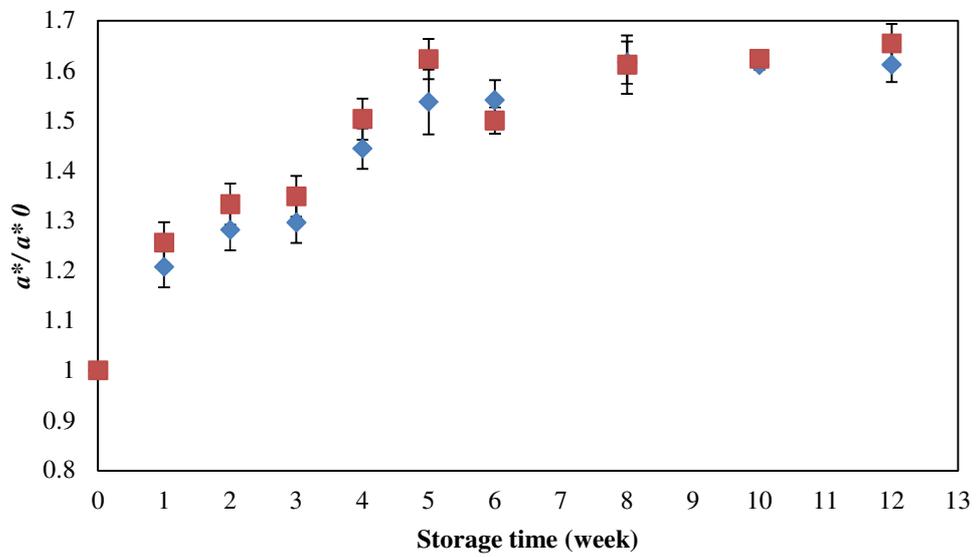


Figure 4.21 a^* value of sweet corn kernels sterilized for 16(♦), and 20(■) minutes at 122 °C during storage at 50°C

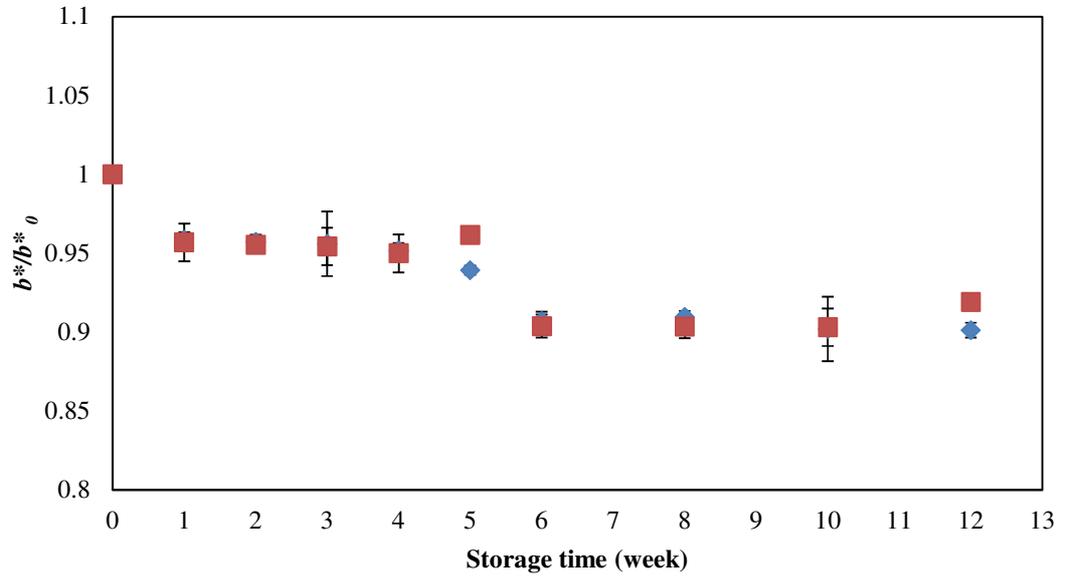


Figure 4.22 b^* value of sweet corn kernels sterilized for 16(♦), and 20(■) minutes at 122 °C during storage at 30°C

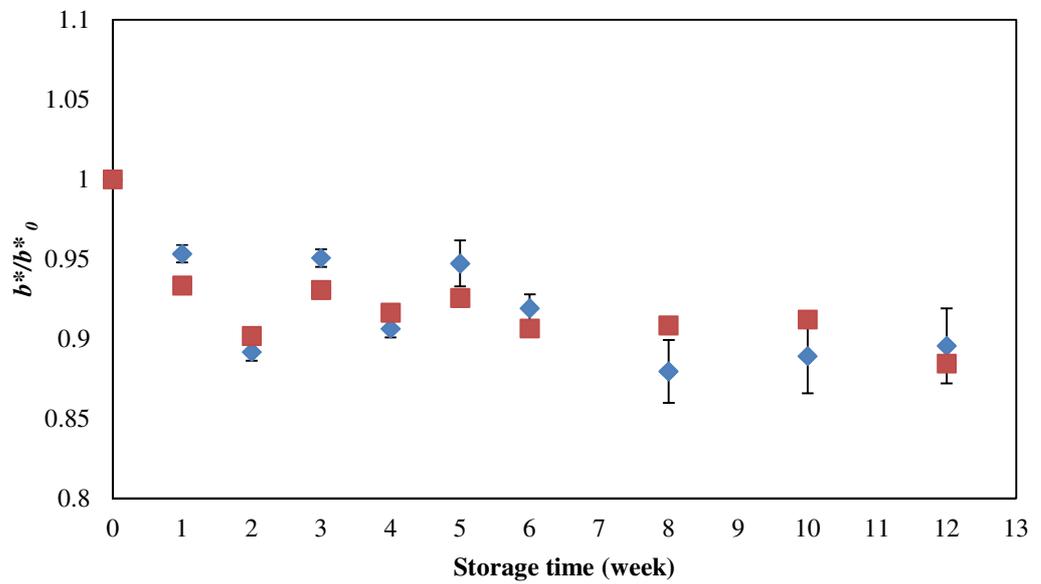


Figure 4.23 b^* value of sweet corn kernels sterilized for 16(♦), and 20(■) minutes at 122 °C during storage at 40°C

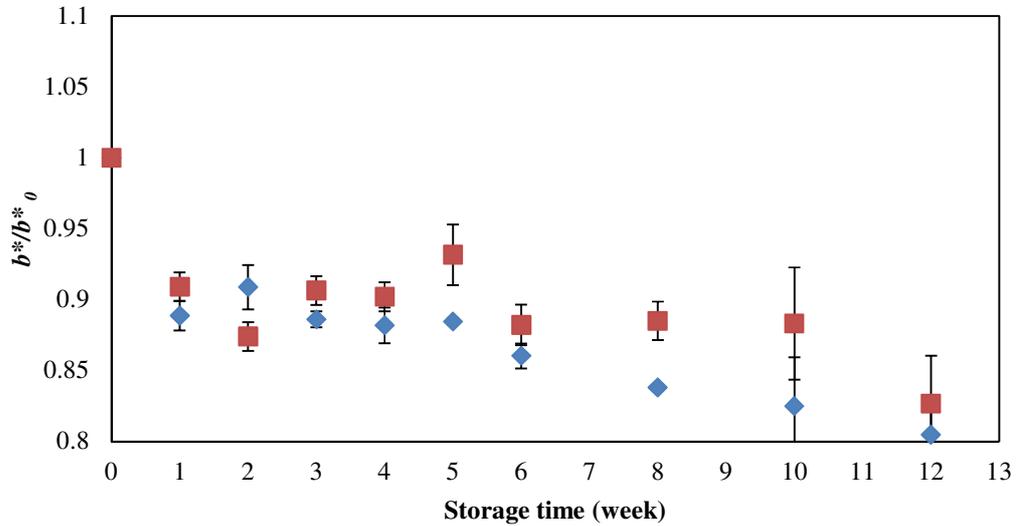


Figure 4.24 b^* value of sweet corn kernels sterilized for 16(◆), and 20(■) minutes at 122 °C during storage at 50°C

4.1.6 Total soluble phenolic content of sweet corn kernels

The Folin-Ciocalteu assay was used to determine total soluble phenolics in sweet corn kernels. The total soluble phenolic content was expressed as milligrams of gallic acid per kg of sample. The effects of sterilization times on total soluble phenolic content are shown in Figures 4.25-4.27.

The rapid loss in total soluble phenolics compound in sweet corn kernel at 1-4 weeks of storage temperature (30, 40 and 50°C) was observed. This correlated with oxidation of phenolics compound with the increase in browning of sweet corn kernels at the initial time of storage.

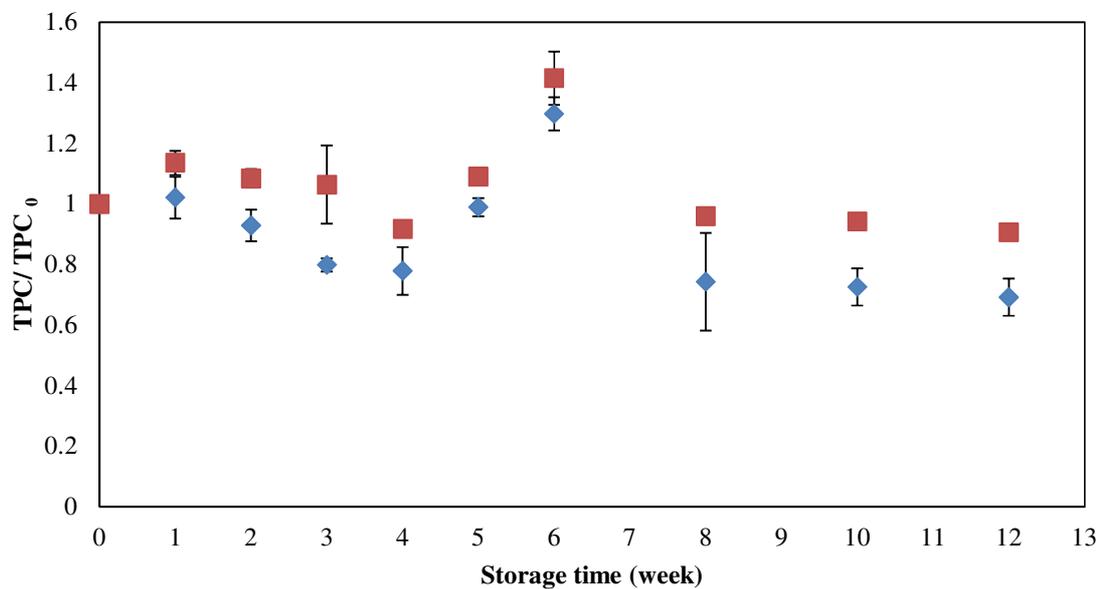


Figure 4.25 Total soluble phenolic content of sweet corn kernels sterilized for 16(◆), and 20(■) minutes at 122 °C during storage at 30°C

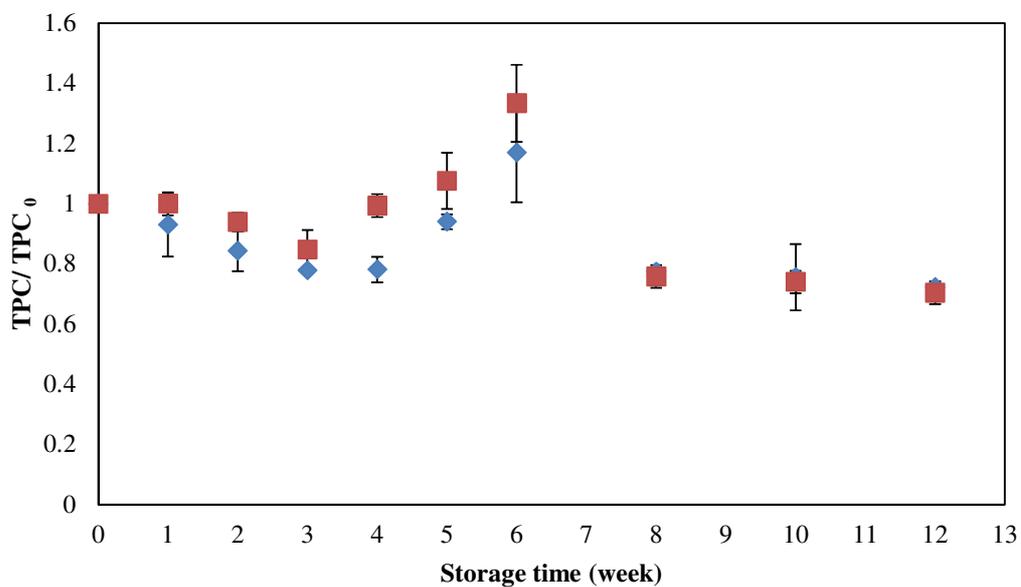


Figure 4.26 Total soluble phenolic content of sweet corn kernels sterilized for 16(◆), and 20(■) minutes at 122 °C during storage at 40°C

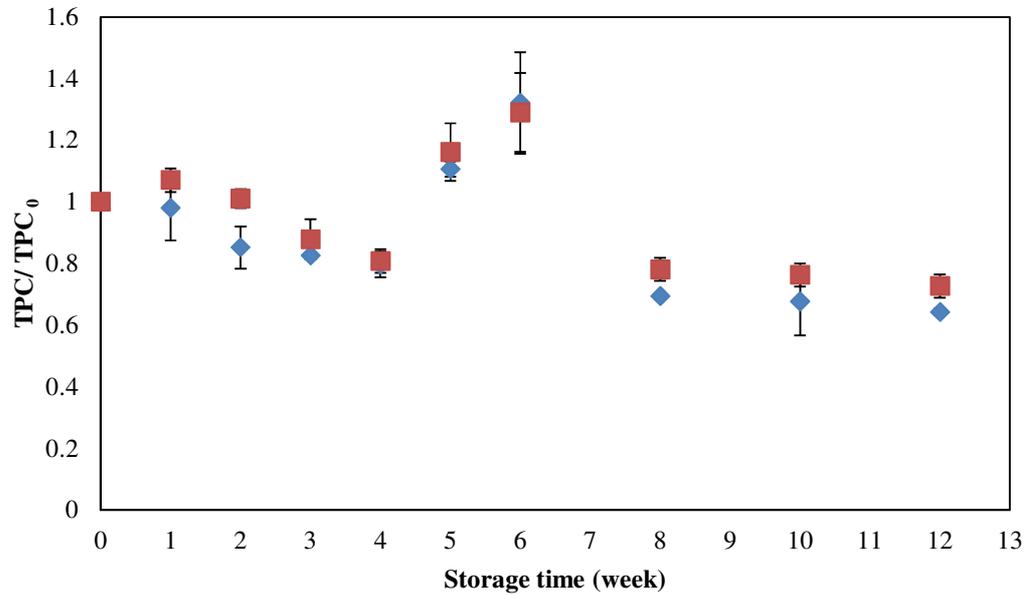


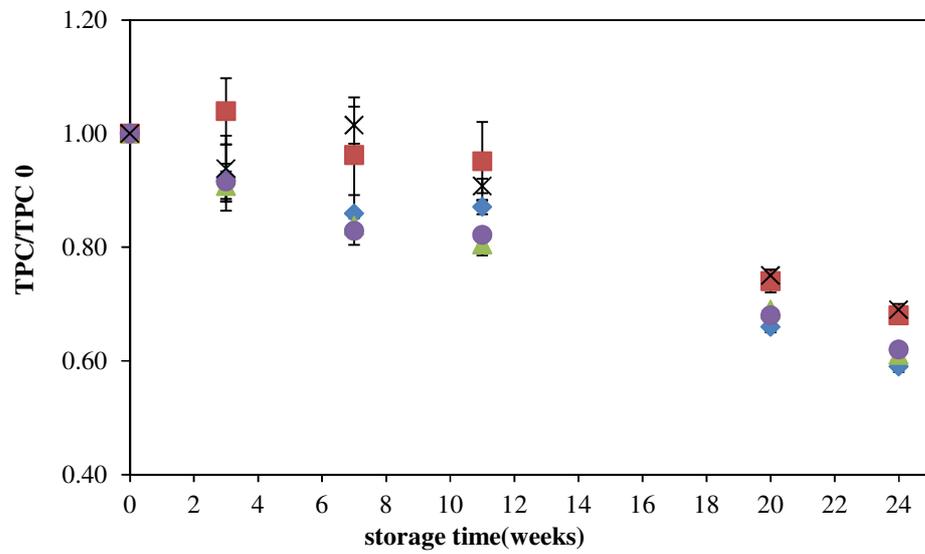
Figure 4.27 Total soluble phenolic content of sweet corn kernels sterilized for 16(◆), and 20(■) minutes at 122 °C during storage at 50°C

4.2 Effect of anti-browning agents on browning inhibition

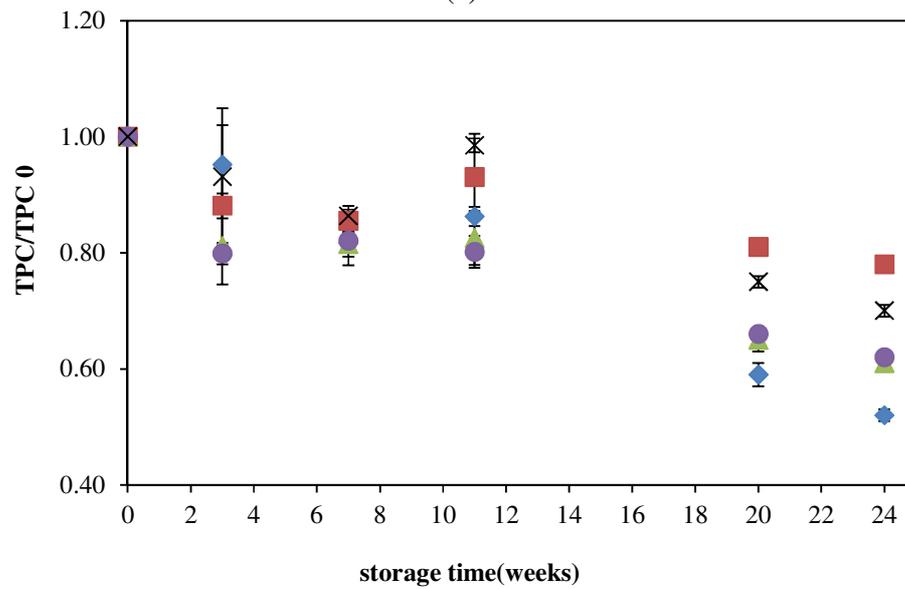
This part of experiment was conducted to investigate the effects of anti-browning agents used in previous study. It was the continued work of the previous research (Ms Benjawam Jermujjarit) to observe the effect of anti-browning agents when the storage time was prolonged.

4.2.1 Total Soluble Phenolic Content

After storage for 6 months the total soluble phenolic content ratios of the product using F_0 value of 8 min showed a rapid decrease in TPC content at all sample. The TPC ratios of F_0 value = 6 min was higher than that of $F_0 = 8$ min. The decrease in total soluble phenolic content ratio may indicate its participation in phenolic autoxidation resulting in browning of sweet corn during an initial stage of storage (Figures 4.28 and 4.29).

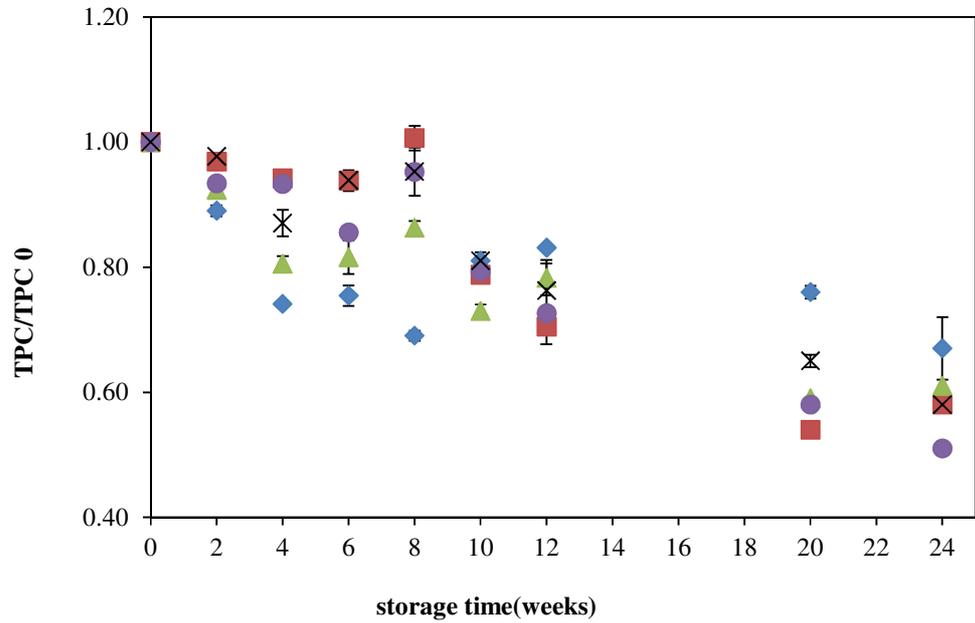


(a)

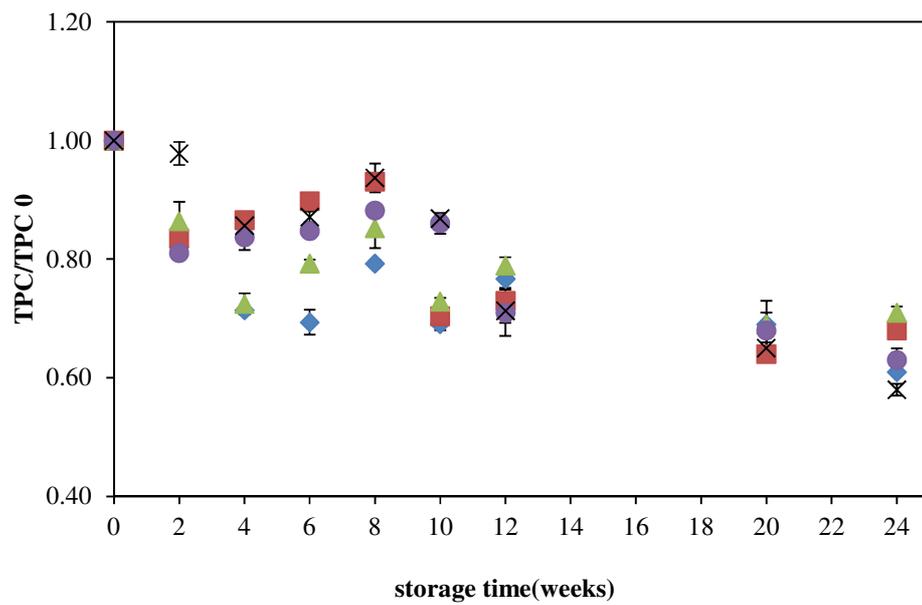


(b)

Figure 4.28 Total soluble phenolic content ratios of sweet corn kernels of the control (◆) compared with those containing anti-browning agents AS (■), CI (▲), SE (●) and SE+CI (×) with the use of $F_0 = 6$ min and storage temperatures of 30°C (a) and 40°C (b)



(a)

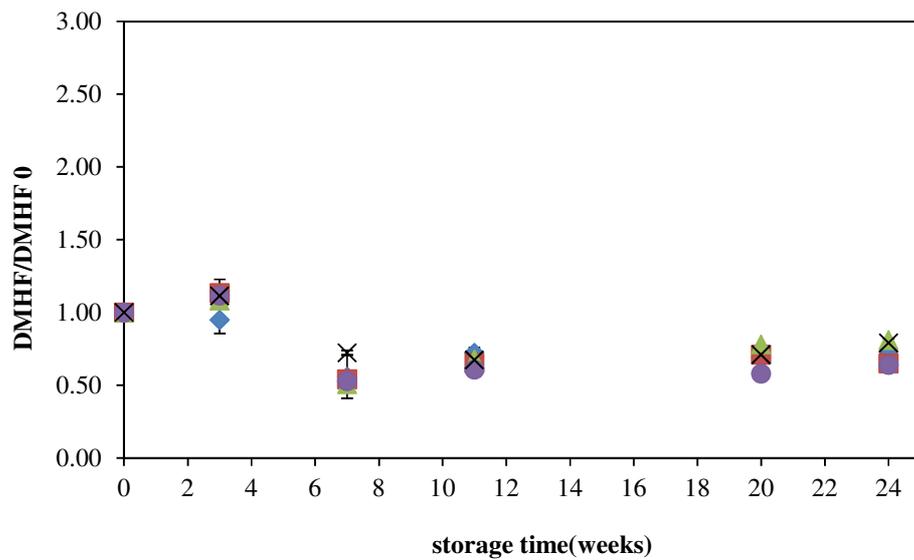


(b)

Figure 4.29 Total soluble phenolic content ratios of sweet corn kernels of the control (◆) compared with those containing anti-browning agents AS (■), CI (▲), SE (●) and SE+CI (×) with the use of $F_0 = 8$ min and storage temperatures of 30°C (a) and 40°C (b)

4.2.2 DMHF Content

After 6 month-storage, DMHF content ratio ($DMHF/DMHF_0$) of sweet corn kernels increased with increasing storage time and temperature. For F_0 value of 8 min, DMHF content ratios slowly increased after 4 week-storage and seemed to be unchanged after 20 week-storage (Figure 4.31). For F_0 value of 6 min, the DMHF ratios showed no significant change during 24 week-storage (Figure 4.30). From the results, the process using F_0 value of 8 min provided more brown pigment formation from Maillard reaction than the process using F_0 value of 6 min. In addition, Maillard reaction took place more in the later time of storage when compared with the initial storage time.



(a)

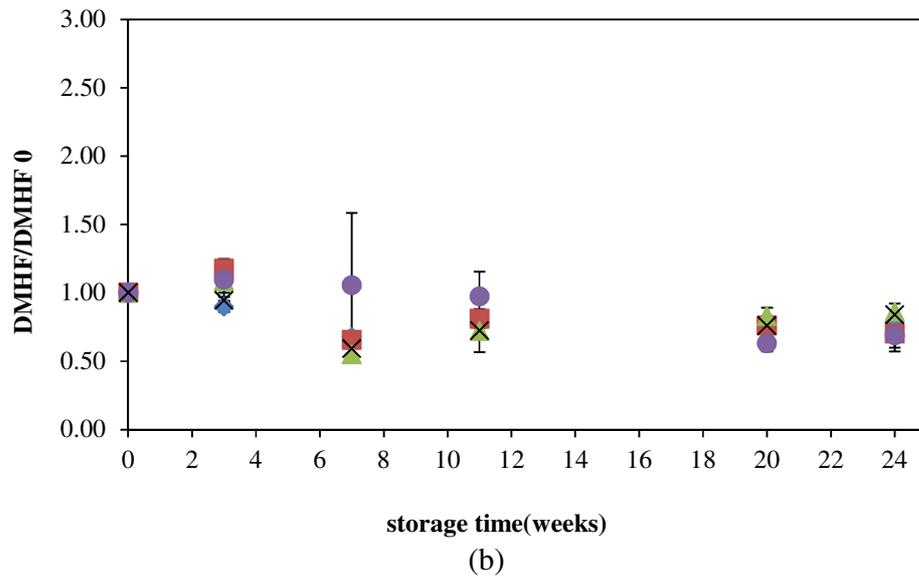
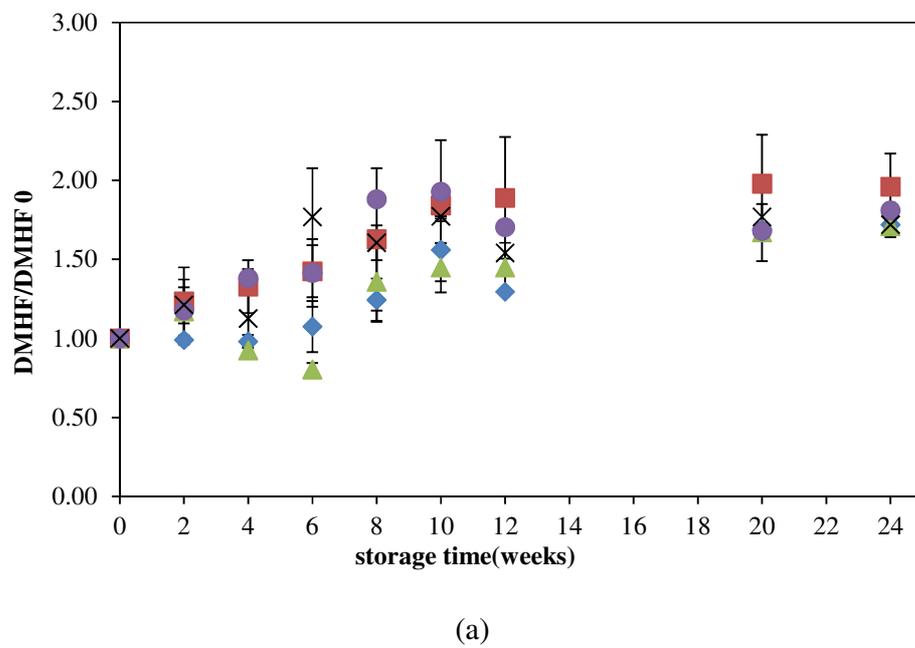
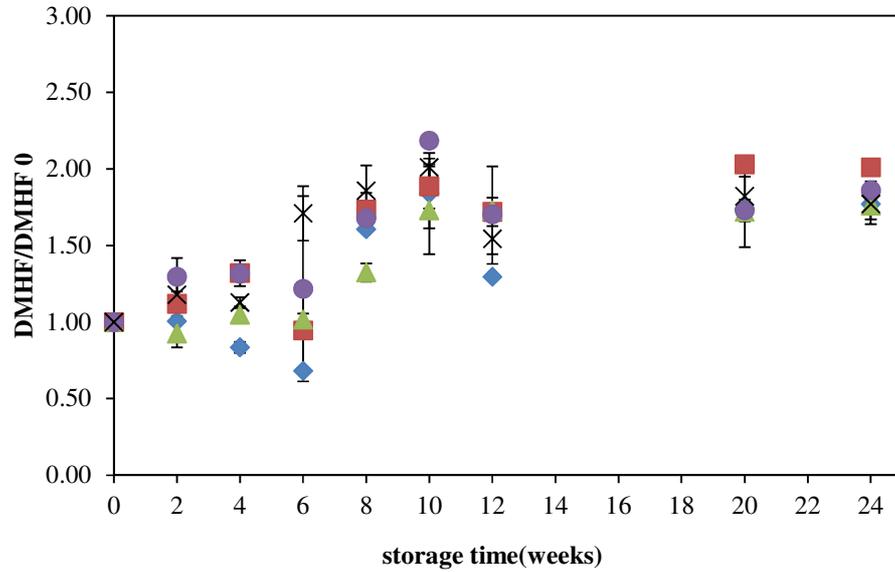


Figure 4.30 DMHF content ratios of sweet corn kernels of the control (◆) compared with those containing anti-browning agents AS (■), CI (▲), SE (●) and SE+CI (×) with the use of $F_0 = 6$ min and storage temperatures of 30°C (a) and 40°C (b)





(b)

Figure 4.31 DMHF content ratios of sweet corn kernels of the control (◆)

compared with those containing anti-browning agents AS (■), CI (▲),

SE (●) and SE+CI (×) with the use of $F_0 = 8$ min and storage temperatures

of 30°C (a) and 40°C (b)

4.3 Kinetic study of color change of sweet corn kernels during storage

This study aimed to evaluate the kinetics of color change of sweet corn kernels stored at temperatures of 30, 40, and 50°C. The apparent order of reaction for these indicators was derived from experimental data using the kinetic equation for zero order (4.1) and first orders (4.2).

$$\text{Zero-order kinetics: } C = C_0 \pm k_0.t \quad (4.1)$$

$$\text{First-order kinetics: } C = C_0.\exp(-k_1.t) \quad (4.2)$$

Where C is the value of property considered for any times

C_0 is the initial value of this property

t is time

k_0 is the rate constant for zero order chemical reaction

and k_1 is the rate constant for first order chemical reaction

In each case the best fit was selected based on the linear correlation coefficient (R^2) and the rate constant (k) at each temperature determined from the slope of the straight line.

The influence of temperature on the reaction rate has been shown by many available experimental kinetic data to fit the Arrhenius relationship.

$$k = k_0 e^{-E_a/RT} \quad (4.3)$$

where k_0 is pre-exponential factor

R is gas constant, 0.0083 KJ/mole

T is temperature in K

E_a is activation energy needed by the reaction component to have a high probability of occurring.

Taking logarithms of Eq. (4.3):

$$\ln k = \ln k_0 - E_a/RT \quad (4.4)$$

Chemical reactions causing the color degradation of sweet corn kernels were associated with pigment (carotenoid) degradation, phenolic autooxidation and Maillard reaction. Only phenolic autooxidation and Maillard reaction that were related to color change of this product. So kinetic study of two reactions were described in details.

4.3.1 Kinetic study of total soluble phenolic content

The results of the zero and first order kinetic experiments of sweet corn kernels with sterilization times of 16 and 20 minute showed the decrease in TPC/TPC₀ with increasing storage time and temperature as shown in Figures 4.32 - 4.35. And results of zero and first order kinetics of TPC/TPC₀ are presented in Table 4.1 and 4.2

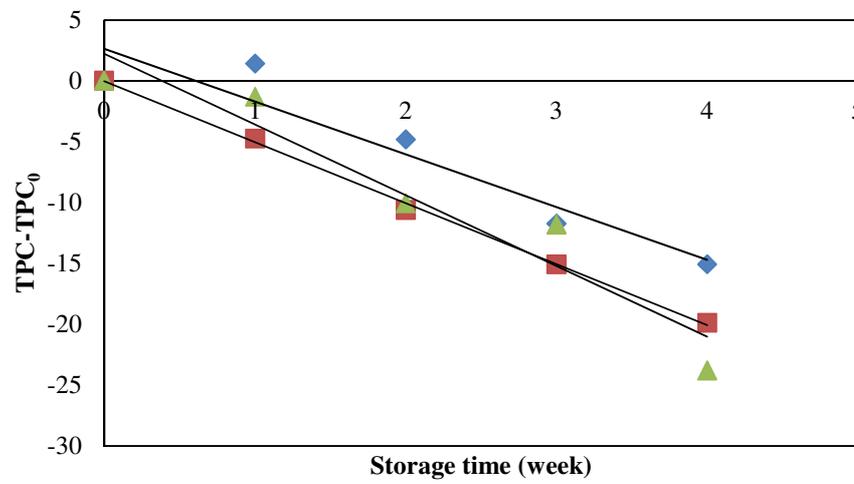


Figure 4.32 The zero-order kinetics of TPC/TPC₀ value of sweet corn kernels sterilized at 122 °C for 16 minutes and storage at 30(◆), 40(■) and 50(▲) °C

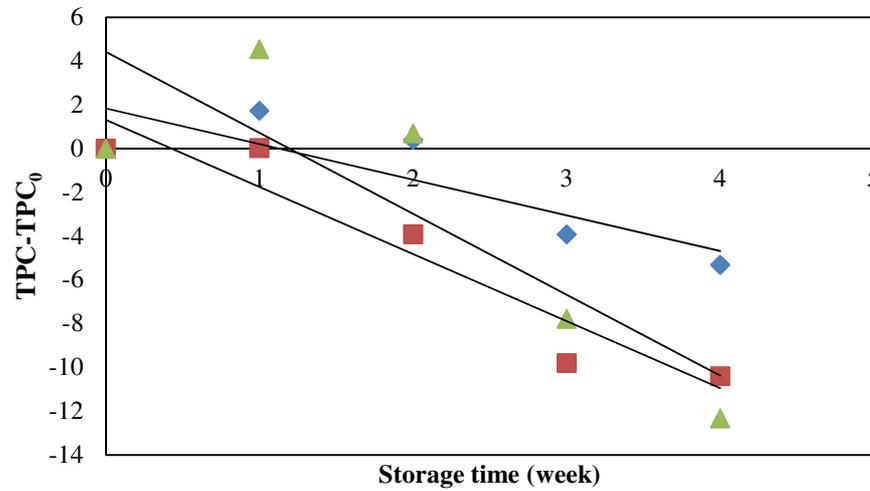


Figure 4.33 The zero order kinetics of TPC/TPC₀ value of sweet corn kernels sterilized at 122 °C for 20 minutes and storage at 30(◆), 40(■) and 50(▲) °C

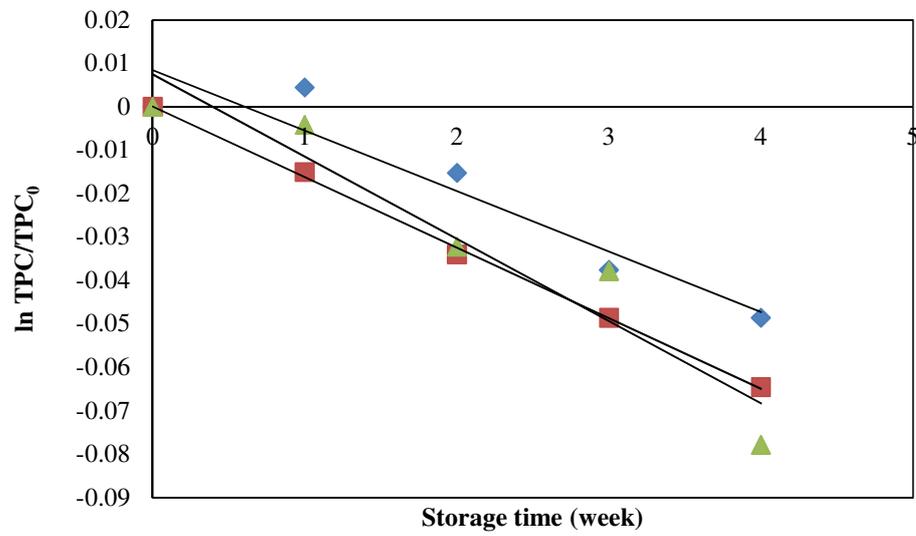


Figure 4.34 The first order kinetics of $\ln \text{TPC}/\text{TPC}_0$ value of sweet corn kernels sterilized at 122 °C for 16 minutes and storage at 30(◆), 40(■) and 50(▲) °C

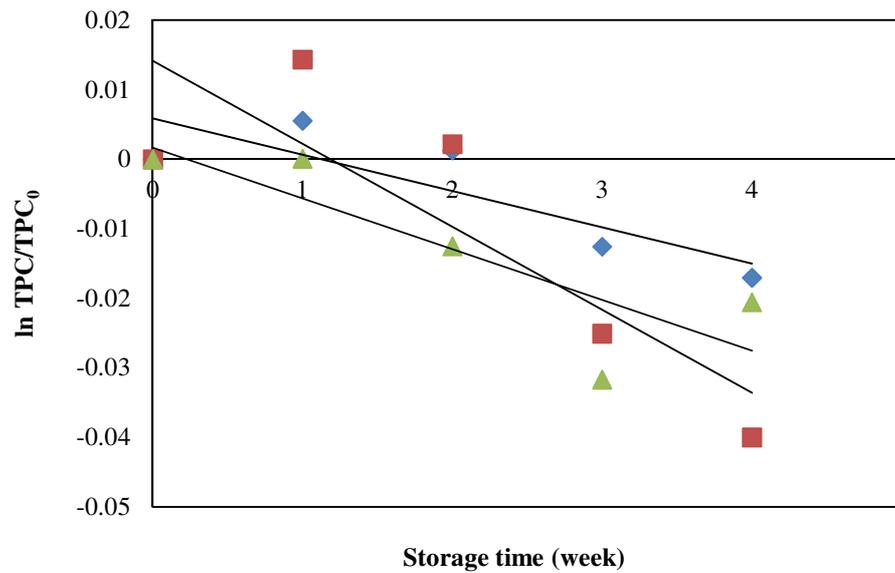


Figure 4.35 The first order kinetics of $\ln \text{TPC}/\text{TPC}_0$ value of sweet corn kernels sterilized at 122 °C for 20 minutes and storage at 30(◆), 40(■) and 50(▲) °C

Table 4.1 Chemical kinetic parameters for zero and first reaction order for TPC/TPC₀ of sweet corn kernels sterilized at 122 °C for 16 minutes and storage at 30, 40 and 50 °C

Parameter	Zero order			First order		
	Temperature			Temperature		
	30°C	40°C	50°C	30°C	40°C	50°C
k_0 or k_1 *	0.013	0.015	0.018	0.013	0.016	0.018
R^2	0.903	0.998	0.918	0.903	0.998	0.914

Table 4.2 Chemical kinetic parameters for zero and first reaction order for TPC/TPC₀ of sweet corn kernels sterilized at 122 °C for 20 minutes and storage at 30, 40 and 50 °C

Parameter	Zero order			First order		
	Temperature			Temperature		
	30°C	40°C	50°C	30°C	40°C	50°C
k_0 or k_1 *	0.005	0.007	0.011	0.005	0.009	0.011
R^2	0.722	0.715	0.722	0.723	0.906	0.724

* k_0 is the rate constant for zero order reaction and k_1 is the rate constant for first order reaction

The value of the rate constant ($-k$) increase with a rise in storage temperature. From Tables 4.1 and 4.2, the first order reaction model was chosen since it showed better correlation with the experimental data via the value of R^2 than the zero order reaction model. For sterilization time of 16 minutes at 122 °C, the first order reaction was determined using the Arrhenius equation as shown in Figure 4.36-4.37. A value of $E_a = 13.25$ kJ/mole and $\ln k_0 = 0.939$ week⁻¹ were obtained with a determination coefficient $R^2 = 0.980$. For

sterilization time of 20 minutes at 122 °C, a value of $E_a = 32.18$ kJ/mole and $\ln k_0 = 7.555$ week⁻¹ were obtained with a determination coefficient $R^2 = 0.935$.

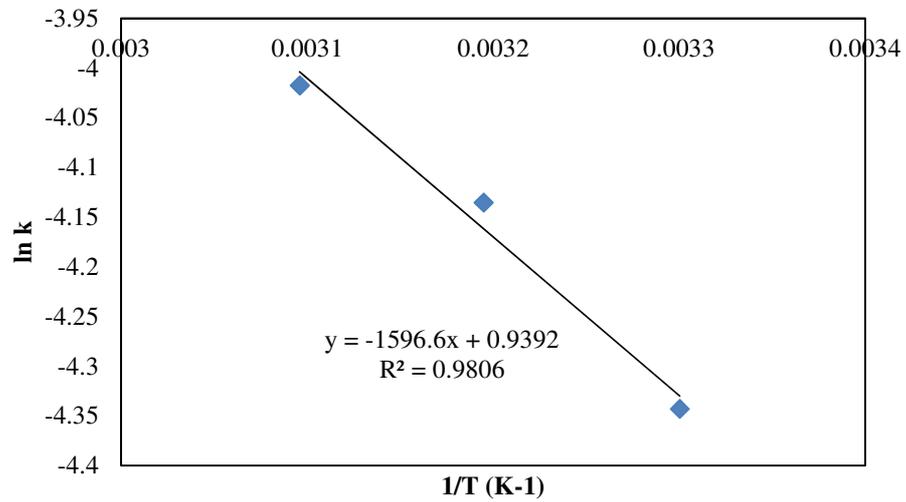


Figure 4.36 Arrhenius plot for TPC/TPC₀ value of sweet corn kernels sterilized at 122 °C for 16 minutes

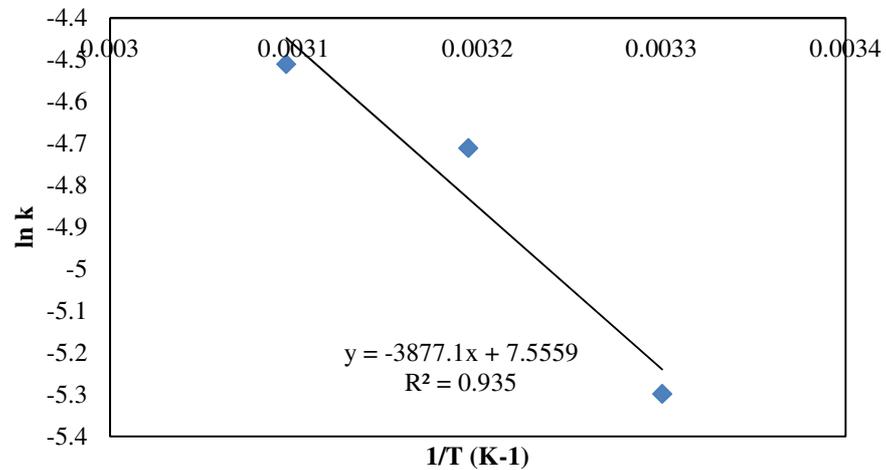


Figure 4.37 Arrhenius plot for TPC/TPC₀ value of sweet corn kernels sterilized at 122 °C for 20 minutes

4.3.2 Kinetic study of reducing sugar content

The results of the zero and first order kinetic experiments of sweet corn kernels which were sterilized at 122 °C for 16 and 20 minutes showed the decrease in RS/RS_0 with increasing storage time and temperature as shown in Figures 4.37 - 4.40. And the results of zero and first order reaction kinetics of RS/RS_0 are presented in Table 4.3 and 4.4

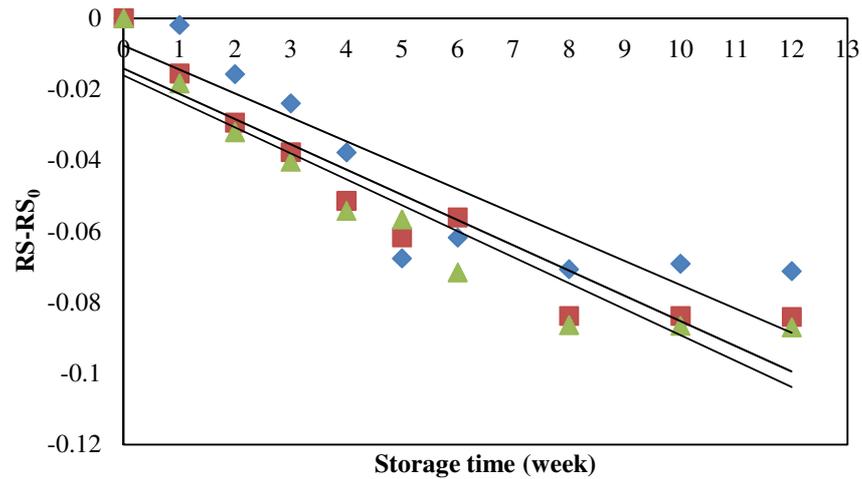


Figure 4.38 The zero order kinetics of RS/RS_0 value of sweet corn kernels sterilized at 122 °C for 16 minutes and storage at 30(◆), 40(■) and 50(▲) °C

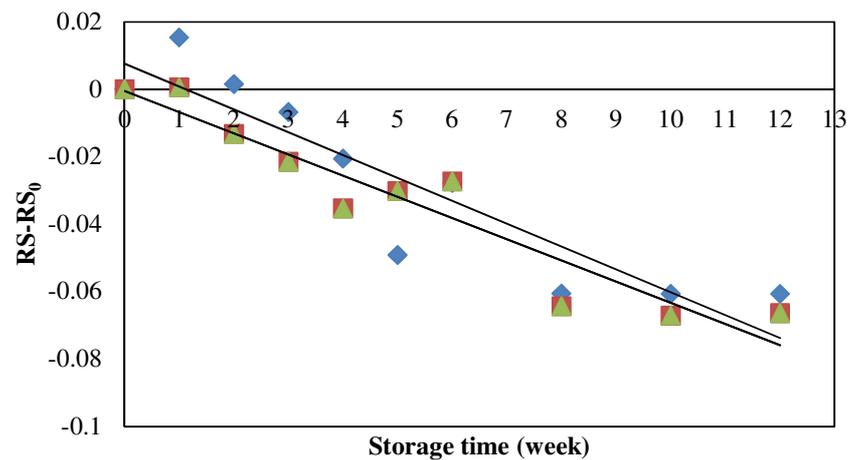


Figure 4.39 The zero order kinetics of RS/SS_0 value of sweet corn kernels sterilized at 122 °C for 20 minutes and storage at 30(◆), 40(■) and 50(▲) °C

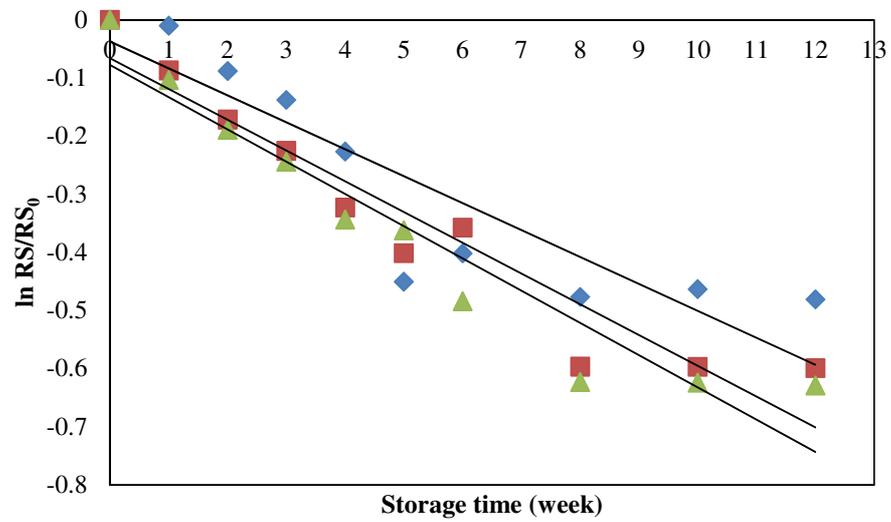


Figure 4.40 The first order kinetics of $\ln RS/RS_0$ value of sweet corn kernels sterilized at $122\text{ }^{\circ}\text{C}$ for 16 minutes and storage at $30(\blacklozenge)$, $40(\blacksquare)$ and $50(\blacktriangle)$ $^{\circ}\text{C}$

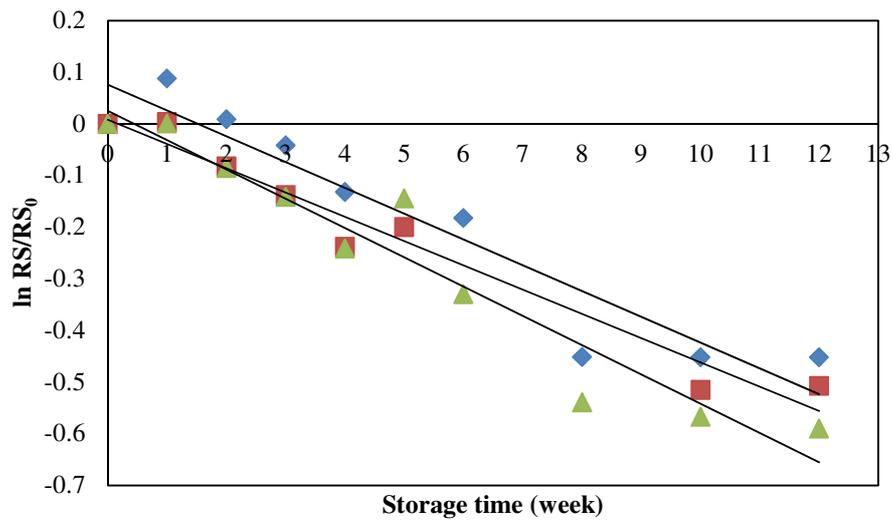


Figure 4.41 The first order kinetics of $\ln RS/SC_0$ value of sweet corn kernels sterilized at $122\text{ }^{\circ}\text{C}$ for 20 minutes and storage at $30(\blacklozenge)$, $40(\blacksquare)$ and $50(\blacktriangle)$ $^{\circ}\text{C}$

Table 4.3 Chemical kinetic parameters for zero and first reaction order for RS/RS₀ of sweet corn kernels sterilized at 122 °C for 16 minutes during storage.

Parameter	Zero order			First order		
	Temperature			Temperature		
	30°C	40°C	50°C	30°C	40°C	50°C
k_0 or k_1 *	0.036	0.038	0.039	0.046	0.053	0.055
R^2	0.801	0.89	0.886	0.811	0.917	0.918

Table 4.4 Chemical kinetic parameters for zero and first reaction order for RS/RS₀ of sweet corn kernels sterilized at 122 °C for 20 minutes during storage

Parameter	Zero order			First order		
	Temperature			Temperature		
	30°C	40°C	50°C	30°C	40°C	50°C
k_0 or k_1 *	0.03	0.033	0.037	0.051	0.053	0.056
R^2	0.902	0.906	0.923	0.902	0.961	0.923

* k_0 is the rate constant for zero order reaction and k_1 is the rate constant for first order reaction

The value of the rate constant ($-k$) increased with a rise in storage temperature. From Tables 4.3 and 4.4, the first order reaction model was chosen since it showed better correlation with the experimental data via the value of R^2 than the zero order reaction model. For sterilization time 16 minutes at 122 °C, the first order reaction was determined using the Arrhenius equation as shown in Figures 4.42-4.43. A value of $E_a = 7.30$ kJ/mole and $\ln k_0 = 0.160$ week⁻¹ were obtained with a determination coefficient $R^2 = 0.908$. For sterilization time of 20 minutes, a value of $E_a = 3.79$ kJ/mole and $\ln k_0 = 1.472$ week⁻¹ were obtained with a determination coefficient $R^2 = 0.985$.

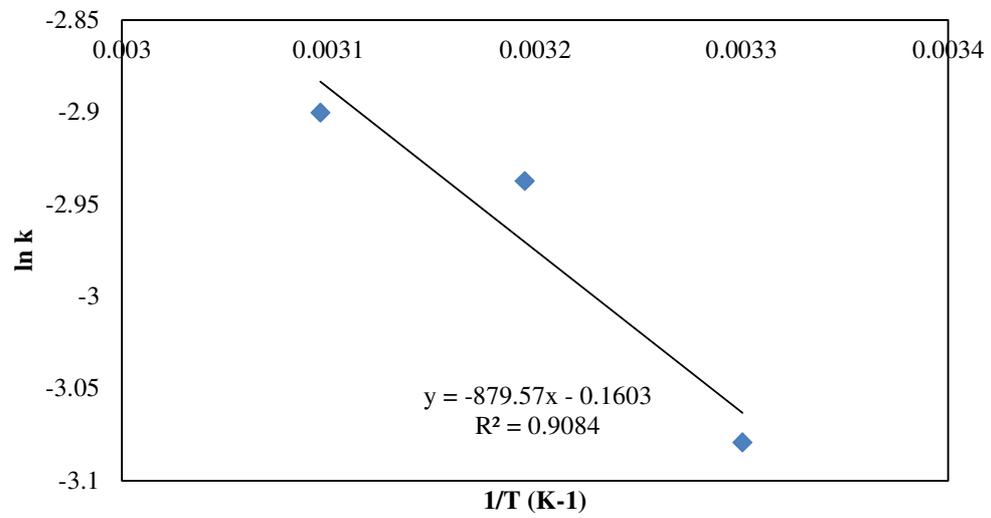


Figure 4.42 Arrhenius plot for RS/RS_0 value of sweet corn kernels sterilized at $122^\circ C$ for 16 minutes

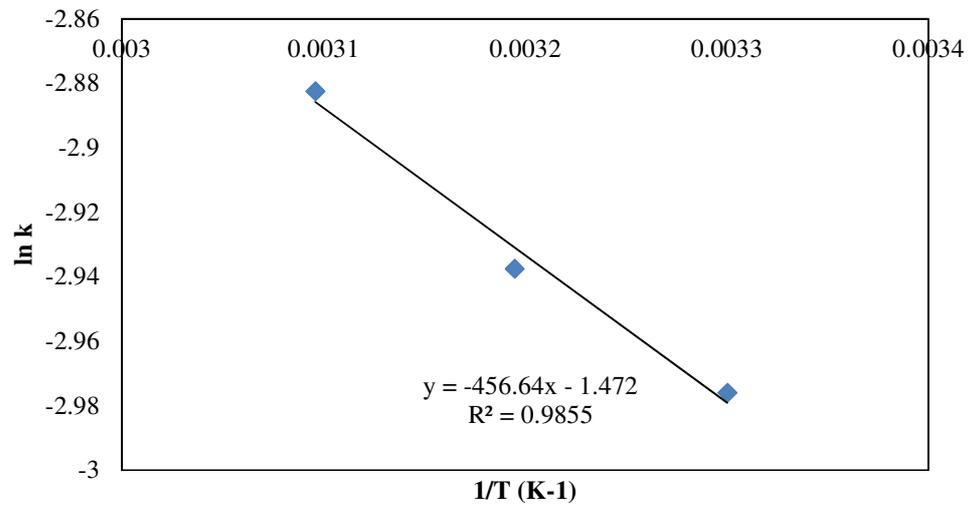


Figure 4.43 Arrhenius plot for RS/RS_0 value of sweet corn kernels sterilized at $122^\circ C$ for 20 minutes

CHAPTER 5 CONCLUSION

5.1 Conclusion

In this study the effects of sterilization time as well as the effects of different storage temperatures on color change of sweet corn kernels in brine packed in retortable carton during storage were investigated. The sterilization times of 16 and 20 minutes at 122°C were studied during storage at 30, 40 and 50°C for 12 weeks. The effect of sterilization time on product qualities was indicated by the change in colorimetric parameters (CIE L^* a^* b^*), oxygen content in the headspace, dissolved oxygen, total soluble phenolics content, browning index (BI) and total carotenoid content. It was found with longer sterilization time the L^* value tended to decrease while a^* value increased but b^* value was quite fluctuated. The rapid loss in total soluble phenolics at the first time storage (4 weeks) resulting from the oxidation of phenolic compound also correlated with an increase in the browning of sweet corn kernels. Furthermore, an evolution of reducing sugar content and browning index of whole sweet corn kernel that indicate non enzymatic browning reaction showed no significant difference between samples during storage at all storage temperatures (30, 40 and 50°C). However, at high storage temperature the product sterilized for 20 minutes become darker than that of 16 minutes. For the reducing sugar content of sweet corn, it rather declined after two-week storage and seem to be constant after storage for 8 weeks. For the total carotenoid content, the results showed that it was quite fluctuated and no significant differences between samples with different sterilization times were observed due to the stability of carotenoids in the systems with minimum oxygen content. It can be concluded that the color change of sweet corn kernel has no effect of carotenoid degradation.

It could be concluded that the autoxidation of phenolics compound and Maillard reaction were the major causes of color change in sweet corn in brine when it was packed in semi-rigid containers. The reaction may take place during the initial stage of processing and continued under the influence of storage temperature. However, change in color was observed when samples treated with different sterilization times were compared, the samples with sterilization time of 16 minutes gave better color than those of 20 minutes.

For the auto-oxidation of phenolic, it was indicated by a decrease in total soluble phenolic content ratio (TPC/TPC_0). The evolution of TPC/TPC_0 during storage was found to follow first order reaction kinetics. The effect of temperature on the kinetic constants was described by an Arrhenius equation and the activation energy of 16 and 20 minutes obtained were 13.25 and 32.18 kJ/mole, respectively. For the Maillard reaction, it was indicated by a decrease in reducing sugar content ratio (RS/RS_0). The evolution of RS/RS_0 during storage was found to follow first order reaction kinetics. The effect of temperature on the kinetic constants was described by an Arrhenius equation and the activation energy of 16 and 20 minutes obtained were 7.30 and 3.79 kJ/mole, respectively.

Regarding the effects of anti-browning agent on browning inhibition, the anti-browning agents, namely 200 ppm ascorbic acid, 200 ppm sodium erythorbate, 0.01% (w/w) citric acid, and the mixture of 200 ppm sodium erythorbate and 0.01% (w/w) citric acid, with the use of $F_0 = 6$ and 8 minutes were studied during storage at 30 and 40°C for 24 weeks. The results obtained were compared with the control where no additive was added. No significant differences in all browning parameters investigated were found between samples among different anti-browning agents studied. This may be because the anti-browning agent cannot prevent the browning problem of sweet corn kernel or it may be the storage time of 24 weeks was too short to observe the change.

5.2 Recommendation

The production process of sweet corn kernel in brine when it is packed in flexible or semi-rigid container should avoid unit operations that allow for excessive heat and oxygen inclusion into the products due to phenolic autoxidation and Maillard reaction potential. Moreover, the products should be stored at as low a temperature as possible to delay the browning reaction.

For browning inhibition, it is recommended to find a new anti-browning agent that can prevent the browning problem or the storage time should be increased to observe the change.

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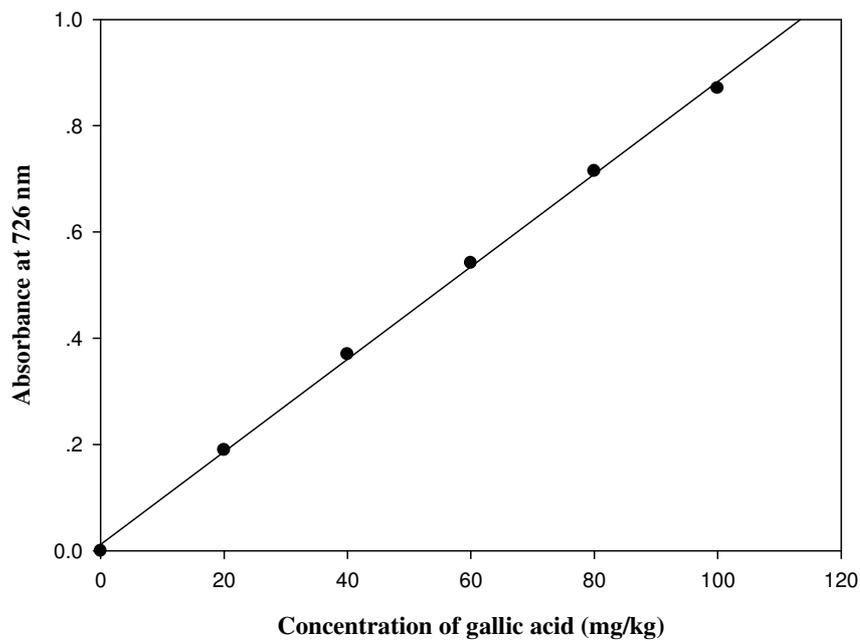
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APPENDIX A

Calibration Curve for Total Soluble Phenolics Content

Table A.1 Absorbance at 726 nm for Total Soluble Phenolics Content

Concentration of gallic acid (mg/kg)	Absorbance at 726 nm			
	Rep 1	Rep 2	Avg	SE
0	0.000	0.000	0.000	0.000
20	0.190	0.189	0.190	0.001
40	0.363	0.377	0.370	0.010
60	0.539	0.544	0.542	0.004
80	0.715	0.714	0.715	0.001
100	0.872	0.869	0.871	0.002

**Figure A.1** The relationship between absorbance value at 726 nm and concentration of gallic acid

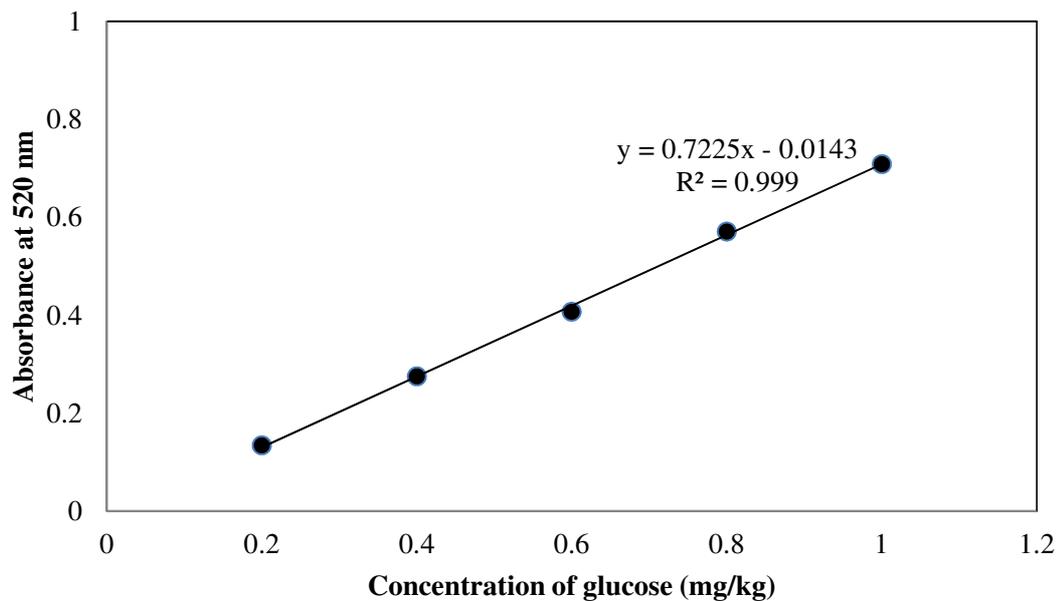
The concentration of gallic acid can be calculated from equation, obtained from calibration curve as follows:

$$Y = 0.0087X + 0.012$$

Where : Y = Absorbance value (726nm) and X = concentration of gallic acid content

Table A.2 Absorbance at 520 nm for Reducing Sugar Content

Concentration Reducing sugar (mg/kg)	Absorbance at 520 nm			
	Rep 1	Rep 2	Avg	SE
0	0.00	0.000	0.000	0.000
20	0.130	0.138	0.134	0.005
40	0.278	0.272	0.275	0.004
60	0.405	0.41	0.4075	0.003
80	0.573	0.569	0.571	0.002
100	0.707	0.71	0.7085	0.002

**Figure A.2** The relationship between absorbance value at 520 nm and concentration of glucose

The concentration of glucose can be calculated from equation, obtained from calibration curve as follows:

$$Y = 0.722x - 0.014$$

Where : Y = Absorbance value (520nm) and X = concentration of glucose content

APPENDIX B

Experimental Data

B. Study of the effects of sterilization time and storage temperature on product quality

B.1 Oxygen Content

Table B.1 Head-space oxygen (mL) of the products sterilized for 16 minutes and storage at 30°C

Time(weeks)	Rep1	Rep2	Avg	SD
0	0.72	0.67	0.69	0.0346
1	0.59	0.55	0.57	0.0283
2	0.39	0.39	0.39	0.0028
3	0.28	0.30	0.29	0.0177
4	0.23	0.23	0.23	0.0028
5	0.19	0.19	0.19	0.0028
6	0.21	0.21	0.21	0.0007
8	0.20	0.20	0.20	0.0007
10	0.19	0.19	0.19	0.0028
12	0.15	0.15	0.15	0.0028

Table B.2 Head-space oxygen (mL) of product sterilized for 16 minutes and storage at 40°C

Time(weeks)	Rep1	Rep2	Avg	SD
0	0.27	0.29	0.28	0.0177
1	0.23	0.22	0.22	0.0064
2	0.20	0.20	0.20	0.0014
3	0.20	0.20	0.20	0.0014
4	0.20	0.20	0.20	0.0007
5	0.19	0.19	0.19	0.0028
6	0.15	0.15	0.15	0.0028
8	0.35	0.35	0.35	0.0028
10	0.31	0.31	0.31	0.0028
12	0.20	0.20	0.20	0.0007

Table B.3 Head-space oxygen (mL) of the products sterilized 16 minutes and storage at 50°C

Time(weeks)	Rep1	Rep2	Avg	SD
0	0.25	0.27	0.26	0.0177
1	0.21	0.20	0.20	0.0064
2	0.18	0.18	0.18	0.0014
3	0.18	0.18	0.18	0.0014
4	0.18	0.18	0.18	0.0007
5	0.17	0.17	0.17	0.0028
6	0.13	0.13	0.13	0.0028
8	0.33	0.33	0.33	0.0028
10	0.29	0.29	0.29	0.0028
12	0.18	0.18	0.18	0.0007

Table B.4 Head-space oxygen (mL) of the products sterilized 20 minutes and storage at 30°C

Time(weeks)	Rep1	Rep2	Avg	SD
0	0.72	0.69	0.71	0.0212
1	0.67	0.74	0.71	0.0495
2	0.54	0.50	0.52	0.0283
3	0.69	0.64	0.67	0.0354
4	0.69	0.60	0.65	0.0636
5	0.46	0.70	0.58	0.1697
6	0.62	0.55	0.59	0.0495
8	0.72	0.76	0.74	0.0283
10	0.68	0.92	0.80	0.1697
12	0.60	0.54	0.57	0.0424

Table B.5 Head-space oxygen (mL) of the products sterilized 20 minutes and storage at 40°C

Time(weeks)	Rep1	Rep2	Avg	SD
0	0.72	0.69	0.71	0.0212
1	0.58	0.93	0.76	0.2475
2	0.75	0.62	0.69	0.0919
3	0.61	0.71	0.66	0.0707
4	0.58	0.81	0.70	0.1626
5	0.90	0.46	0.68	0.3111
6	0.54	0.71	0.63	0.1202
8	0.88	0.74	0.81	0.0990
10	0.72	0.79	0.76	0.0495
12	0.50	0.54	0.52	0.0283

Table B.6 Head-space oxygen (mL) of the products sterilized 20 minutes and storage at 50°C

Time(weeks)	Rep1	Rep2	Avg	SD
0	0.72	0.69	0.71	0.0212
1	0.84	0.60	0.72	0.1697
2	0.54	0.66	0.60	0.0849
3	0.41	0.53	0.47	0.0849
4	0.79	0.41	0.60	0.2687
5	0.49	0.72	0.61	0.1626
6	0.82	0.87	0.85	0.0354
8	0.72	0.79	0.76	0.0495
10	0.69	0.74	0.72	0.0354
12	0.94	0.72	0.83	0.1556

Table B.7 Dissolve oxygen (mg/L) of the products sterilized 16 minutes and storage at 30°C

Time(weeks)	Rep1	Rep2	Avg	SD
0	0.93	0.98	0.96	0.0354
1	0.78	0.85	0.82	0.0495
2	0.72	0.77	0.75	0.0354
3	0.86	0.86	0.86	0.0000
4	0.82	0.85	0.84	0.0212
5	0.78	0.8	0.79	0.0141
6	0.77	0.8	0.79	0.0212
8	0.8	0.79	0.80	0.0071
10	0.79	0.83	0.81	0.0283
12	0.89	0.66	0.78	0.1626

Table B.8 Dissolve oxygen (mg/L) of the products sterilized 16 minutes and storage at 40°C

Time(weeks)	Rep1	Rep2	Avg	SD
0	1.1	1.29	1.20	0.1344
1	0.89	0.98	0.94	0.0636
2	0.84	0.9	0.87	0.0424
3	0.9	0.97	0.94	0.0495
4	0.86	0.91	0.89	0.0354
5	0.95	0.99	0.97	0.0283
6	0.89	0.8	0.85	0.0636
8	0.78	0.74	0.76	0.0283
10	0.83	0.81	0.82	0.0141
12	0.73	0.85	0.79	0.0849

Table B.9 Dissolve oxygen (mg/L) of the products sterilized 16 minutes and storage at 50°C

Time(weeks)	Rep1	Rep2	Avg	SD
0	1.14	1.33	1.24	0.1344
1	0.93	1.02	0.98	0.0636
2	0.88	0.94	0.91	0.0424
3	0.94	1.01	0.98	0.0495
4	0.9	0.95	0.93	0.0354
5	0.99	1.03	1.01	0.0283
6	0.93	0.84	0.89	0.0636
8	0.82	0.78	0.80	0.0283
10	0.87	0.85	0.86	0.0141
12	1.14	1.33	1.24	0.1344

Table B.10 Dissolve oxygen (mg/L) of the products sterilized 20 minutes and storage at 30°C

Time(weeks)	Rep1	Rep2	Avg	SD
0	1.32	1.39	1.36	0.0495
1	1.05	1.05	1.05	0.0000
2	1.31	1.38	1.35	0.0495
3	1.41	1.20	1.31	0.1485
4	1.56	1.32	1.44	0.1697
5	1.50	1.18	1.34	0.2263
6	3.17	2.97	3.07	0.1414
8	1.77	1.63	1.70	0.0990
10	1.56	1.57	1.57	0.0071
12	1.25	1.21	1.23	0.0283

Table B.11 Dissolve oxygen (mg/L) of the products sterilized 20 minutes and storage at 40°C

Time(weeks)	Rep1	Rep2	Avg	SD
0	1.32	1.39	1.36	0.0495
1	1.06	0.89	0.98	0.1202
2	1.28	1.25	1.27	0.0212
3	1.17	1.28	1.23	0.0778
4	1.15	1.38	1.27	0.1626
5	1.13	1.17	1.15	0.0283
6	1.56	1.58	1.57	0.0141
8	1.84	1.90	1.87	0.0424
10	1.48	1.53	1.51	0.0354
12	1.20	1.08	1.14	0.0849

Table B.12 Dissolve oxygen (mg/L) of the products sterilized 20 minutes and storage at 50°C

Time(weeks)	Rep1	Rep2	Avg	SD
0	1.32	1.39	1.36	0.0495
1	1.81	0.70	1.26	0.7849
2	1.57	1.45	1.51	0.0849
3	1.04	1.14	1.09	0.0707
4	1.08	1.19	1.14	0.0778
5	1.13	1.28	1.21	0.1061
6	1.04	1.07	1.06	0.0212
8	1.86	1.89	1.88	0.0212
10	1.74	1.87	1.81	0.0919
12	1.08	1.09	1.09	0.0071

B.2 Color degradation

Determination of color degradation in CIE (L^* a^* and b^*) color system.

Table B.13 L^* value of sweet corn with sterilized 16 minutes and storage at 30°C

Time(weeks)	Rep1	Rep2	Rep3	Rep4	Avg	SE
0	73.2	73.77	74.9	74.11	73.995	0.0102
1	73.8	74.44	73.62	73.88	73.935	0.004781
2	73.4	74.04	73.22	73.48	73.535	0.004781
3	73.3	73.94	73.12	73.38	73.435	0.020478
4	73.3	73.94	73.12	73.38	73.435	0.004781
5	72.03	72.48	72.05	72.27	72.2075	0.002861
6	70.39	69.74	69.74	70.6	70.1175	0.006004
8	69.37	69.8	69.97	69.48	69.655	0.003759
10	69.32	69.75	69.92	69.43	69.605	0.020478
12	69.24	68.92	69.31	69.77	69.31	0.004737

Table B.14 a^* value of sweet corn with sterilized 16 minutes and storage at 30°C

Time(weeks)	Rep1	Rep2	Rep3	Rep4	Avg	SE
0	6.69	6.91	6.57	6.87	6.76	0.07102
1	6.15	6.17	6.39	5.83	6.135	0.034109
2	6.65	6.67	6.89	6.33	6.635	0.034109
3	6.75	6.77	6.99	6.43	6.735	0.034109
4	7.75	6.77	7.99	7.43	7.485	0.034109
5	7.99	8.74	8.34	7.71	8.195	0.065896
6	7.28	6.91	8.69	7.98	7.715	0.11642
8	7.55	7.97	8.49	7.53	7.885	0.066787
10	7.95	8.37	8.89	7.93	8.285	0.021862
12	8.43	8.48	8.27	8.59	8.4425	0.019676

Table B.15 b^* value of sweet corn with sterilized 16 minutes and storage at 30°C

Time(weeks)	Rep1	Rep2	Rep3	Rep4	Avg	SE
0	45.36	44.15	44.92	44.55	44.745	0.958548
1	45.29	44.08	44.85	44.48	44.675	0.957048
2	45.24	44.03	44.8	44.43	44.625	0.955977
3	45.04	43.83	44.6	44.23	44.425	0.951692
4	44.21	43.99	45.67	41.5	43.8425	0.939214
5	39.79	42.26	44.57	42.73	42.3375	0.906973
6	42.39	41.63	43.01	42.83	42.465	0.909704
8	41.99	41.23	42.61	42.43	42.065	0.9021
10	41.68	43.18	41.42	42	42.07	0.901243
12	45.36	44.15	44.92	44.55	44.745	0.958548

Table B.16 L^* value of sweet corn with sterilized 16 minutes and storage at 40°C

Time(weeks)	Rep1	Rep2	Rep3	Rep4	Avg	SE
0	73.2	73.77	74.9	74.11	73.995	0.0102
1	72.53	73.44	72.37	71.93	72.5675	0.008576
2	72.13	73.04	71.97	71.53	72.1675	0.008576
3	72.03	72.94	71.87	71.43	72.0675	0.048576
4	71.03	71.94	70.87	70.43	71.0675	0.008576
5	70.65	70.98	70.07	71.19	70.7225	0.066017
6	68.4	68.25	68.33	68.51	68.3725	0.00149
8	68.28	69.15	68.6	68.91	68.735	0.005105
10	68.21	69.08	68.53	68.84	68.665	0.048576
12	67.29	67.2	67.43	67.38	67.325	0.001372

Table B.17 a^* value of sweet corn with sterilized 16 minutes and storage at 40°C

Time(weeks)	Rep1	Rep2	Rep3	Rep4	Avg	SE
0	6.69	6.91	6.57	6.87	6.76	0.07102
1	6.09	7.57	7.44	6.84	6.985	0.100014
2	6.59	8.07	7.94	7.34	7.485	0.100014
3	6.69	8.17	8.04	7.44	7.585	0.100014
4	7.69	9.17	9.04	8.44	8.585	0.100014
5	9.05	8.68	8.62	9.8	9.0375	0.080286
6	8.29	8.13	8.64	7.83	8.685	0.049908
8	8.36	8.92	8.85	9.38	8.816667	0.061758
10	8.53	9.09	9.02	9.55	9.0475	0.008727
12	9.56	9.59	9.89	9.78	9.56	0.023249

Table B.18 b^* value of sweet corn with sterilized 16 minutes and storage at 40°C

Time(weeks)	Rep1	Rep2	Rep3	Rep4	Avg	SE
0	45.36	44.15	44.92	44.55	44.745	0.958548
1	44.87	44.32	44.43	44.36	44.7425	0.005443
2	44.8	44.25	44.36	44.29	44.4	0.005443
3	44.75	44.2	44.31	44.24	43.9675	0.005443
4	44.55	44	44.11	44.04	44.175	0.005443
5	43.5	43.84	44.99	44.53	44.215	0.01438
6	43.07	42.47	43.39	42.69	41.1575	0.008727
8	40.29	40.27	41.57	42.09	40.52	0.019704
10	40.31	40.29	41.59	42.11	41.075	0.023249
12	40.96	40.76	42.66	42.84	40.96	0.023494

Table B.19 L^* value of sweet corn with sterilized 16 minutes and storage at 50°C

Time(weeks)	Rep1	Rep2	Rep3	Rep4	Avg	SE
0	73.2	73.77	74.9	74.11	73.995	0.0102
1	69.53	70.41	69.52	70.47	68.93	0.007147
2	69.13	70.01	69.12	70.07	68.065	0.007147
3	69.03	69.91	69.02	69.97	66.6675	0.007147
4	68.03	68.91	68.02	68.97	64.97	0.007147
5	66.07	67.3	66.6	66.69	63.3975	0.006812
6	63.54	63.13	63.86	63.9	61.54	0.004822
8	62.24	61.62	60.75	60.33	60.87333	0.011606
10	61.74	61.12	60.25	59.83	60.19	0.007147
12	58.64	59.03	58.16	58.32	58.64	0.005193

Table B.20 a^* value of sweet corn with sterilized 16 minutes and storage at 50°C

Time(weeks)	Rep1	Rep2	Rep3	Rep4	Avg	SE
0	6.69	6.91	6.57	6.87	6.76	0.07102
1	7.85	8.22	8.51	8.07	8.525	0.040984
2	8.35	8.72	9.01	8.57	9.1325	0.040984
3	8.45	8.82	9.11	8.67	9.6225	0.040984
4	9.45	9.82	10.11	9.67	10.1475	0.040984
5	10.28	11.04	10.1	10.15	10.4975	0.064835
6	10.31	10.21	10.82	10.33	10.7	0.040447
8	10.55	11.24	10.91	11	10.83	0.042335
10	10.85	11.54	11.21	11.3	11.225	0.008706
12	11.09	10.68	11.11	10.71	10.8975	0.034658

Table B.21 b^* value of sweet corn with sterilized 16 minutes and storage at 50°C

Time(weeks)	Rep1	Rep2	Rep3	Rep4	Avg	SE
0	45.36	44.15	44.92	44.55	44.745	0.958548
1	42.36	42.61	40.84	40.12	41.4825	0.010197
2	42.29	42.54	40.77	40.05	41.4125	0.010197
3	42.24	42.49	40.72	40	41.3625	0.010197
4	42.04	42.29	40.52	39.8	41.1625	0.010197
5	43.03	43.52	38.95	39.66	41.29	0.021396
6	39.96	39.82	40.74	40.1	40.155	0.014145
8	39.59	40.49	38.19	38.2	39.1175	0.013514
10	39.55	40.45	38.15	38.16	39.0775	0.039591
12	38.84	36.38	38.13	36.91	37.565	0.03396

Table B.22 L^* value of sweet corn with sterilization time 20 minutes and storage at 30°C

Time(weeks)	Rep1	Rep2	Rep3	Rep4	Avg	SE
0	74.98	74.05	73.86	73.01	73.98	0.8083
1	74.3	73.52	72.54	74.48	73.71	0.8843
2	73.9	73.12	72.14	74.08	73.31	0.8843
3	73.8	73.02	72.04	73.98	73.21	0.8843
4	72.8	72.02	71.04	72.98	72.21	0.8843
5	71.23	71.67	71.27	71.12	71.32	0.2402
6	70.18	70.01	69.14	69.22	69.64	0.5338
8	69.59	70.04	70.14	68.95	69.68	0.5423
10	69.44	69.89	70.09	68.8	69.56	0.5720
12	68.88	68.95	68.77	69.05	68.91	0.1179

Table B.23 a^* value of sweet corn with sterilization time 20 minutes and storage at 30°C

Time(weeks)	Rep1	Rep2	Rep3	Rep4	Avg	SE
0	6.53	6.42	6.45	6.51	6.48	0.0512
1	6.63	6.65	6.55	6.53	6.59	0.0589
2	7.13	7.15	7.05	7.03	7.09	0.0589
3	7.23	7.25	7.15	7.13	7.19	0.0589
4	8.23	8.25	8.15	8.13	8.19	0.0589
5	8.17	8.03	8.39	8.3	8.22	0.1569
6	7.35	7.45	7.84	7.62	7.57	0.2146
8	8.02	8.1	7.56	8.63	8.08	0.4385
10	8.13	8.21	7.67	8.84	8.21	0.4813
12	8.6	8.49	8.46	8.29	8.46	0.1283

Table B.24 b^* value of sweet corn with sterilization time 20 minutes storage and at 30°C

Time(weeks)	Rep1	Rep2	Rep3	Rep4	Avg	SE
0	45.02	46.87	45.02	46.78	45.92	1.0428
1	43.34	44.1	44.95	43.39	43.95	0.7546
2	43.27	44.03	44.88	43.32	43.88	0.7546
3	43.22	43.98	44.83	43.27	43.83	0.7546
4	43.02	43.78	44.63	43.07	43.63	0.7546
5	45.12	43.65	44.28	43.58	44.16	0.7147
6	39.82	41.64	42.33	42.24	41.51	1.1659
8	42.01	40.85	39.26	43.86	41.50	1.9382
10	42.14	40.8	39.21	43.81	41.49	1.9561
12	42.98	42.64	42.21	41.01	42.21	0.8598

Table B.25 L^* value of sweet corn with sterilization time 20 minutes and storage at 40°C

Time(weeks)	Rep1	Rep2	Rep3	Rep4	Avg	SE
0	74.98	74.05	73.86	73.01	73.98	0.8083
1	72.48	72.51	72.37	72.42	72.45	0.0624
2	72.08	72.11	71.97	72.02	72.05	0.0624
3	71.98	72.01	71.87	71.92	71.95	0.0624
4	70.98	71.01	70.87	70.92	70.95	0.0624
5	70.32	69.82	70.42	70.65	70.30	0.3501
6	68.17	67.76	68.15	67.82	67.98	0.2152
8	67.82	68.16	68.34	67.8	68.03	0.2646
10	67.67	68.01	68.21	67.65	67.89	0.2725
12	66.79	66.65	66.99	66.67	66.78	0.1561

Table B.26 a^* value of sweet corn with sterilization time 20 minutes and storage at 40°C

Time(weeks)	Rep1	Rep2	Rep3	Rep4	Avg	SE
0	6.53	6.42	6.45	6.51	6.48	0.0512
1	6.5	7.49	7.11	6.72	6.96	0.4368
2	7.99	7	7.61	7.22	7.46	0.4368
3	8.09	7.1	7.71	7.32	7.56	0.4368
4	9.09	8.1	8.71	8.32	8.56	0.4368
5	9.38	8.93	9.42	9.02	9.19	0.2486
6	8.58	8.37	9.19	8.47	8.65	0.3685
8	9.04	9.18	9.39	9.43	9.26	0.1831
10	9.15	9.29	9.6	9.54	9.40	0.2114
12	9.51	9.48	9.31	8.95	9.31	0.2572

Table B.27 b^* value of sweet corn with sterilization time 20 minutes and storage at 40°C

Time(weeks)	Rep1	Rep2	Rep3	Rep4	Avg	SE
0	45.02	46.87	45.02	46.78	45.92	1.0428
1	43.43	43	43.17	41.83	42.86	0.7075
2	43.36	42.93	43.1	41.76	42.79	0.7075
3	43.31	42.88	43.05	41.71	42.74	0.7075
4	43.11	42.68	42.85	41.51	42.54	0.7075
5	42.77	42.24	42.98	42.01	42.50	0.4513
6	41.01	40.09	43.09	42.31	41.63	1.3354
8	42.19	41.35	41.09	42.23	41.72	0.5816
10	42.32	41.3	41.04	42.18	41.71	0.6351
12	39.95	41.14	40.49	40.89	40.62	0.5193

Table B.28 L^* value of sweet corn with sterilization time 20 minutes and storage at 50°C

Time(weeks)	Rep1	Rep2	Rep3	Rep4	Avg	SE
0	74.98	74.05	73.86	73.01	73.98	0.8083
1	68.94	68.73	69.54	69.48	69.17	0.3998
2	68.54	68.33	69.14	69.08	68.77	0.3998
3	68.44	68.23	69.04	68.98	68.67	0.3998
4	67.44	67.23	68.04	67.98	67.67	0.3998
5	67.42	68.03	68.31	67.89	67.91	0.3719
6	65.63	65.43	66.06	66.08	65.80	0.3224
8	64.17	63.78	63.52	63.39	63.72	0.3439
10	64.02	63.63	63.37	63.24	63.57	0.3439
12	59.16	59.68	58.59	59.63	59.27	0.5073

Table B.29 a^* value of sweet corn with sterilization time 20 minutes and storage at 50°C

Time(weeks)	Rep1	Rep2	Rep3	Rep4	Avg	SE
0	6.53	6.42	6.45	6.51	6.48	0.0512
1	8.26	8.31	8.23	7.74	8.14	0.2654
2	8.76	8.81	8.73	8.24	8.64	0.2654
3	8.86	8.91	8.83	8.34	8.74	0.2654
4	9.86	9.91	9.83	9.34	9.74	0.2654
5	10.64	10.73	10.55	10.14	10.52	0.2606
6	9.97	9.6	9.62	9.68	9.72	0.1717
8	10.94	10.41	10.02	10.4	10.44	0.3781
10	11.05	10.52	10.33	10.51	10.60	0.3108
12	10.67	11.06	10.69	10.44	10.72	0.2565

Table B.30 b^* value of sweet corn with sterilization time 20 minutes and storage at 50°C

Time(weeks)	Rep1	Rep2	Rep3	Rep4	Avg	SE
0	45.02	46.87	45.02	46.78	45.92	1.0428
1	42.42	41.62	41.35	41.57	41.74	0.4683
2	42.35	41.55	41.28	41.5	41.67	0.4683
3	42.3	41.5	41.23	41.45	41.62	0.4683
4	42.1	41.3	41.03	41.25	41.42	0.4683
5	43.45	41.57	43.7	42.41	42.78	0.9826
6	41.1	39.63	40.43	40.88	40.51	0.6496
8	41.55	40.33	40.18	40.5	40.64	0.6206
10	41.68	40.28	40.13	40.45	40.64	0.7088
12	37.6	40.18	37.52	36.53	37.96	1.5595

B.3 Carotenoid degradation

Determination of total carotenoid degradation.

Table B.31 Total carotenoid content of sweet corn with sterilization time of 16 minutes and storage at 30°C

Time(weeks)	Rep1	Rep2	Rep3	Rep4	Avg	SE
0	586.32	682.48	609.36	683.45	640.40	50.04
1	658.88	571.89	567.48	575.90	593.54	43.70
2	674.88	716.84	711.65	739.11	710.62	26.64
3	684.75	682.27	661.91	669.13	674.51	10.84
4	641.42	691.52	691.24	715.78	684.99	31.24
5	784.08	669.29	727.20	678.66	714.80	52.70
6	690.48	696.43	694.08	696.01	694.25	2.71
8	687.49	699.71	764.36	748.72	725.07	37.23
10	673.66	715.29	649.03	663.11	675.27	28.52
12	692.64	734.57	668.12	682.27	694.40	28.60

Table B.32 Total carotenoid content of sweet corn with sterilization time of 16 minutes and storage at 40°C

Time(weeks)	Rep1	Rep2	Rep3	Rep4	Avg	SE
0	586.32	682.48	609.36	683.45	640.40	50.04
1	602.62	570.14	572.16	571.84	579.19	15.64
2	738.97	724.15	705.10	624.61	698.21	50.99
3	721.57	723.48	726.33	735.94	726.83	6.38
4	805.22	735.73	729.72	764.36	758.76	34.47
5	692.40	700.39	731.57	773.51	724.47	36.80
6	582.22	617.95	615.36	650.94	616.62	28.08
8	601.55	604.18	603.22	611.88	605.21	4.58
10	625.55	608.44	595.16	588.04	604.30	16.50
12	644.71	627.46	613.99	607.32	623.37	16.51

Table B.33 Total carotenoid content of sweet corn with sterilization time of 16 minutes and storage at 50°C

Time(weeks)	Rep1	Rep2	Rep3	Rep4	Avg	SE
0	586.32	682.48	609.36	683.45	640.40	50.04
1	597.90	596.21	684.03	678.71	639.21	48.73
2	619.92	684.04	733.40	721.85	689.80	51.13
3	633.71	643.94	638.84	628.78	636.32	6.53
4	804.89	815.04	866.26	832.80	829.75	26.93
5	683.71	570.54	698.21	616.18	642.16	59.65
6	724.87	703.87	734.48	691.86	713.77	19.41
8	606.82	613.10	606.54	590.05	604.13	9.86
10	595.19	613.10	587.53	566.84	590.66	19.16
12	614.05	632.38	606.54	585.49	609.62	19.41

Table B.34 Total carotenoid content of sweet corn with sterilization time of 20 minutes and storage at 30°C

Time(weeks)	Rep1	Rep2	Rep3	Rep4	Avg	SE
0	744.72	688.75	638.87	695.04	44.0721	744.72
1	586.64	641.17	629.64	621.38	23.8842	586.64
2	652.49	651.24	633.28	622.62	46.9198	652.49
3	626.22	649.07	658.06	643.36	13.5767	626.22
4	713.93	717.83	771.20	732.45	26.3930	713.93
5	711.52	669.44	628.70	670.97	33.8856	711.52
6	686.37	669.13	688.30	689.29	18.2148	686.37
8	592.36	592.06	598.73	726.83	6.4023	592.36
10	643.95	645.79	657.10	711.52	8.3497	643.95
12	663.23	664.50	675.93	713.36	8.2507	663.23

Table B.35 Total carotenoid content of sweet corn with sterilization time of 20 minutes and storage at 40°C

Time(weeks)	Rep1	Rep2	Rep3	Rep4	Avg	SE
0	707.84	744.72	688.75	638.87	695.04	44.0721
1	633.49	628.96	658.86	659.67	645.24	16.2953
2	716.90	744.70	678.90	648.05	697.14	42.4061
3	677.10	648.99	684.75	705.27	679.03	23.2906
4	725.84	799.87	764.36	776.50	766.64	30.9412
5	687.21	589.43	737.40	731.42	686.36	68.3908
6	627.63	666.81	718.72	718.35	682.88	44.1698
8	598.48	608.74	601.78	600.34	602.33	4.4810
10	609.13	590.71	612.06	648.24	615.04	24.0696
12	628.22	609.35	631.19	666.81	633.89	23.9822

Table B.36 Total carotenoid content of sweet corn with sterilization time of 20 minutes and storage at 50°C

Time(weeks)	Rep1	Rep2	Rep3	Rep4	Avg	SE
0	707.84	744.72	688.75	638.87	695.04	44.0721
1	708.89	705.38	678.98	724.42	704.42	18.8689
2	741.48	755.81	743.14	761.78	750.55	9.8507
3	638.84	658.06	643.94	623.54	641.10	14.2501
4	740.66	718.27	697.28	712.52	717.18	17.9821
5	1101.17	1079.68	805.56	784.21	942.65	171.0787
6	686.11	706.56	705.04	667.53	691.31	18.3824
8	596.49	589.01	602.98	584.41	593.22	8.1904
10	576.49	599.80	578.40	561.24	578.98	15.8610
12	595.58	619.08	597.12	580.52	598.08	15.8801

B.4 Reducing sugar

Determination of reducing sugar content

Table B.37 Reducing sugar content of sweet corn with sterilization time of 16 minutes and storage at 30°C

Time(weeks)	Rep1	Rep2	Rep3	Rep4	Avg	SE
0	0.1914	0.1900	0.1934	0.1956	0.1926	0.0252
1	0.1834	0.1820	0.1854	0.1876	0.1846	0.0024
2	0.1696	0.1682	0.1715	0.1738	0.1708	0.0024
3	0.1613	0.1599	0.1633	0.1655	0.1625	0.0024
4	0.1475	0.1461	0.1494	0.1517	0.1487	0.0024
5	0.1395	0.0981	0.1050	0.1329	0.1189	0.0204
6	0.1240	0.1279	0.1210	0.1260	0.1247	0.0029
8	0.1207	0.1185	0.1108	0.1130	0.1157	0.0046
10	0.1193	0.1196	0.1157	0.1146	0.1173	0.0025
12	0.1166	0.1196	0.1130	0.1119	0.1153	0.0035

Table B.38 Reducing sugar content of sweet corn with sterilization time of 16 minutes and storage at 40°C

Time(weeks)	Rep1	Rep2	Rep3	Rep4	Avg	SE
0	0.1914	0.1900	0.1934	0.1956	0.1926	0.0252
1	0.1710	0.1721	0.1696	0.1710	0.1709	0.0010
2	0.1572	0.1583	0.1558	0.1572	0.1571	0.0010
3	0.1489	0.1500	0.1475	0.1489	0.1488	0.0012
4	0.1351	0.1362	0.1337	0.1351	0.1350	0.0012
5	0.1285	0.1204	0.1185	0.1318	0.1236	0.0072
6	0.1307	0.1290	0.1171	0.1315	0.1271	0.0067
8	0.1025	0.1019	0.1028	0.1036	0.1027	0.0007
10	0.1047	0.1011	0.1022	0.1025	0.1026	0.0015
12	0.1025	0.1008	0.1028	0.1036	0.1024	0.0012

Table B.39 Reducing sugar content of sweet corn with sterilization time of 16 minutes and storage at 50°C

Time(weeks)	Rep1	Rep2	Rep3	Rep4	Avg	SE
0	0.1914	0.1900	0.1934	0.1956	0.1926	0.0252
1	0.1666	0.1691	0.1688	0.1682	0.1682	0.0011
2	0.1528	0.1552	0.1550	0.1544	0.1544	0.0011
3	0.1445	0.1470	0.1467	0.1461	0.1461	0.0011
4	0.1307	0.1331	0.1329	0.1323	0.1323	0.0011
5	0.1304	0.1235	0.1345	0.1307	0.1298	0.0046
6	0.1163	0.1146	0.1127	0.1160	0.1149	0.0016
8	0.1008	0.0989	0.0997	0.1006	0.1000	0.0009
10	0.0992	0.0997	0.1006	0.1000	0.0999	0.0006
12	0.0981	0.0992	0.0997	0.1006	0.0994	0.0010

Table B.40 Reducing sugar content of sweet corn with sterilization time of 20 minutes and storage at 30°C

Time(weeks)	Rep1	Rep2	Rep3	Rep4	Avg	SE
0	1.0102	0.9953	0.9801	0.9746	0.9901	0.0160
1	0.9282	0.9171	0.9019	0.8964	0.9109	0.0145
2	0.8591	0.8481	0.8329	0.8273	0.8419	0.0145
3	0.8177	0.8066	0.7914	0.7859	0.8004	0.0145
4	0.7486	0.7376	0.7224	0.7169	0.7314	0.0145
5	0.0854	0.1298	0.1309	0.1249	0.1177	0.0218
6	0.4917	0.8108	0.7459	0.7334	0.7486	0.1400
8	0.5304	0.5138	0.5442	0.5373	0.7376	0.0130
10	0.5373	0.5276	0.5373	0.5221	0.5311	0.0075
12	0.5304	0.5262	0.5304	0.5373	0.5311	0.0046

Table B.41 Reducing sugar content of sweet corn with sterilization time of 20 minutes and storage at 40°C

Time(weeks)	Rep1	Rep2	Rep3	Rep4	Avg	SE
0	1.0102	0.9953	0.9801	0.9746	0.9901	0.0160
1	0.8412	0.8439	0.8301	0.8343	0.8374	0.0063
2	0.7721	0.7749	0.7652	0.7610	0.7683	0.0063
3	0.7307	0.7334	0.7238	0.7196	0.7256	0.0071
4	0.6616	0.6644	0.6547	0.6506	0.6565	0.0071
5	0.1149	0.1293	0.1641	0.1384	0.1439	0.0180
6	0.7624	0.8287	0.5898	0.6105	0.6979	0.1163
8	0.5152	0.5041	0.5069	0.5235	0.5115	0.0105
10	0.5097	0.4986	0.4890	0.4972	0.4949	0.0052
12	0.5014	0.5097	0.4959	0.5028	0.5024	0.0057

Table B.42 Reducing sugar content of sweet corn with sterilization time of 20 minutes and storage at 50°C

Time(weeks)	Rep1	Rep2	Rep3	Rep4	Avg	SE
0	1.0102	0.9953	0.9801	0.9746	0.9901	1.0102
1	0.8273	0.8384	0.8398	0.8343	0.8349	0.8273
2	0.7583	0.7693	0.7707	0.7652	0.7659	0.7583
3	0.7169	0.7279	0.7293	0.7238	0.7244	0.7169
4	0.6478	0.6588	0.6602	0.6547	0.6554	0.6478
5	0.1373	0.1155	0.1691	0.1558	0.1444	0.1373
6	0.5843	0.6064	0.6326	0.5760	0.5998	0.5843
8	0.4917	0.4986	0.4738	0.4820	0.4865	0.4917
10	0.4848	0.4820	0.4572	0.4682	0.4731	0.4848
12	0.4779	0.4710	0.4461	0.4544	0.4624	0.4779

B.6 Total soluble phenolic content

Determination of total carotenoid content reduction.

Table B.43 Total phenolic content of sweet corn with sterilization time of 16 minutes and storage at 30°C

Time(weeks)	Rep1	Rep2	Rep3	Rep4	Avg	SE
0	318.16	316.55	319.54	318.16	318.10	1.2219
1	314.83	317.82	325.86	319.54	319.51	4.6599
2	316.44	315.29	312.99	308.39	313.28	3.5583
3	304.94	302.64	306.09	303.79	304.37	1.4839
4	304.71	300.92	309.54	296.90	303.02	5.3940
5	315.75	318.51	319.66	315.52	317.36	2.0476
6	342.41	338.97	338.62	333.33	338.33	3.7475
8	297.24	302.76	296.90	305.40	300.57	4.1919
10	296.09	301.61	295.75	304.25	303.79	4.1919
12	293.79	299.31	293.45	301.95	296.90	4.1919

Table B.44 Total phenolic content of sweet corn with sterilization time of 16 minutes and storage at 40°C

Time(weeks)	Rep1	Rep2	Rep3	Rep4	Avg	SE
0	318.16	316.55	319.54	318.16	318.10	1.2219
1	315.29	316.09	311.38	310.69	313.36	2.7223
2	307.59	306.44	310.34	305.52	307.47	2.0944
3	310.69	310.57	295.98	294.83	303.02	8.8056
4	302.41	302.41	303.91	304.14	303.22	0.9338
5	316.09	312.07	314.25	313.79	314.05	1.6534
6	332.99	326.90	322.76	336.09	329.68	5.9920
8	301.61	303.22	302.99	302.76	302.64	0.7147
10	300.46	302.07	301.84	301.61	294.83	0.7147
12	298.16	299.77	299.54	299.31	304.14	0.7147

Table B.45 Total phenolic content of sweet corn with sterilization time of 16 minutes and storage at 50°C

Time(weeks)	Rep1	Rep2	Rep3	Rep4	Avg	SE
0	318.16	316.55	319.54	318.16	318.10	1.2219
1	314.71	311.49	323.56	317.36	316.78	5.1172
2	307.13	302.30	308.51	314.14	308.02	4.8715
3	306.21	310.00	305.86	303.10	306.29	2.8348
4	306.21	305.86	303.33	301.72	304.28	2.1326
5	325.63	320.11	332.41	323.10	325.32	5.2417
6	330.69	344.14	342.07	342.99	339.97	6.2454
8	296.55	297.36	297.36	297.70	297.24	0.4877
10	295.40	296.21	296.21	296.55	303.10	0.4877
12	293.10	293.91	293.91	294.25	301.72	0.4877

Table B.46 Total phenolic content of sweet corn with sterilization time of 20 minutes and storage at 30°C

Time(weeks)	Rep1	Rep2	Rep3	Rep4	Avg	SE
0	317.24	320.11	306.09	313.79	314.31	6.0579
1	315.29	319.43	329.54	327.93	323.05	6.8153
2	319.08	314.60	319.89	325.29	319.71	4.3844
3	317.70	318.05	319.20	318.62	318.39	0.6570
4	306.44	306.90	310.80	311.84	308.99	2.7271
5	318.51	322.30	319.77	319.77	320.09	1.5910
6	325.98	347.47	341.26	349.31	341.01	10.5940
8	305.75	305.52	316.90	318.74	311.72	7.0750
10	304.60	304.37	315.75	317.59	318.62	7.0750
12	302.30	302.07	313.45	315.29	311.84	7.0750

Table B.47 Total phenolic content of sweet corn with sterilization time of 20 minutes and storage at 40°C

Time(weeks)	Rep1	Rep2	Rep3	Rep4	Avg	SE
0	317.24	320.11	306.09	313.79	314.31	6.0579
1	315.17	317.24	311.49	313.45	314.34	2.4498
2	310.92	311.49	307.47	311.72	310.40	1.9831
3	299.31	309.43	305.17	304.14	304.51	4.1543
4	312.41	312.53	317.59	313.10	313.91	2.4706
5	326.09	316.44	321.84	312.41	319.20	6.0042
6	336.78	344.60	324.71	337.01	335.78	8.2211
8	297.93	297.01	302.30	297.70	298.74	2.4074
10	296.78	295.86	301.15	296.55	304.14	2.4074
12	294.48	293.56	298.85	294.25	313.10	2.4074

Table B.48 Total phenolic content of sweet corn with sterilization time of 20 minutes and storage at 50°C

Time(weeks)	Rep1	Rep2	Rep3	Rep4	Avg	SE
0	317.24	320.11	306.09	313.79	314.31	6.0579
1	314.14	309.54	325.29	326.44	318.85	8.3241
2	314.25	310.00	318.28	317.47	315.00	3.7593
3	308.51	306.55	305.86	305.17	306.52	1.4368
4	304.60	302.99	299.54	300.80	301.98	2.2512
5	329.77	321.49	326.21	321.38	324.71	4.0530
6	331.49	331.61	337.36	331.38	332.96	2.9325
8	300.80	300.23	299.31	300.57	300.23	0.6570
10	299.66	299.08	298.16	299.43	305.17	0.6570
12	297.36	296.78	295.86	297.13	300.80	0.6570

B.7 Browning index

Determination of browning index.

Table B.49 Browning index of sweet corn with sterilization time of 16 minutes and storage at 30°C

Time(weeks)	Rep1	Rep2	Rep3	Rep4	Avg	SE
0	0.114	0.115	0.125	0.1210	0.1188	0.0052
1	0.116	0.155	0.127	0.128	0.1315	0.0166
2	0.168	0.165	0.147	0.15	0.1575	0.0105
3	0.223	0.238	0.272	0.3	0.2583	0.0346
4	0.295	0.285	0.291	0.293	0.2910	0.0043
5	0.268	0.284	0.317	0.284	0.2883	0.0206
6	0.219	0.21	0.185	0.206	0.2050	0.0144
8	0.278	0.295	0.255	0.27	0.2745	0.0167
10	0.288	0.295	0.275	0.27	0.2190	0.0115
12	0.298	0.305	0.285	0.28	0.2100	0.0115

Table B.50 Browning index of sweet corn with sterilization time of 16 minutes and storage at 40°C

Time(weeks)	Rep1	Rep2	Rep3	Rep4	Avg	SE
0	0.114	0.115	0.125	0.1210	0.1188	0.0052
1	0.117	0.118	0.139	0.13	0.1260	0.0105
2	0.127	0.128	0.131	0.138	0.1310	0.0050
3	0.254	0.251	0.34	0.342	0.2968	0.0511
4	0.361	0.363	0.357	0.351	0.3580	0.0053
5	0.367	0.369	0.371	0.37	0.3693	0.0017
6	0.3188	0.302	0.308	0.319	0.3120	0.0084
8	0.306	0.303	0.309	0.312	0.3075	0.0039
10	0.336	0.333	0.339	0.332	0.3350	0.0032
12	0.346	0.343	0.349	0.342	0.3450	0.0032

Table B.51 Browning index of sweet corn with sterilization time of 16 minutes and storage at 50°C

Time(weeks)	Rep1	Rep2	Rep3	Rep4	Avg	SE
0	0.114	0.115	0.125	0.1210	0.1188	0.0052
1	0.127	0.12	0.113	0.113	0.1183	0.0067
2	0.129	0.121	0.133	0.132	0.1288	0.0054
3	0.324	0.347	0.354	0.34	0.3413	0.0128
4	0.388	0.378	0.364	0.366	0.3740	0.0112
5	0.401	0.398	0.388	0.387	0.3935	0.0070
6	0.327	0.33	0.32	0.32	0.3243	0.0051
8	0.327	0.325	0.304	0.309	0.3163	0.0115
10	0.347	0.355	0.354	0.359	0.3538	0.0050
12	0.357	0.365	0.364	0.369	0.3638	0.0050

Table B.52 Browning index of sweet corn with sterilization time of 20 minutes and storage at 30°C

Time(weeks)	Rep1	Rep2	Rep3	Rep4	Avg	SE
0	0.107	0.104	0.130	0.097	0.110	0.0143
1	0.158	0.155	0.151	0.148	0.153	0.0044
2	0.158	0.152	0.145	0.148	0.151	0.0056
3	0.258	0.263	0.267	0.255	0.158	0.0053
4	0.290	0.292	0.295	0.275	0.152	0.0089
5	0.296	0.309	0.309	0.298	0.145	0.0070
6	0.221	0.214	0.285	0.293	0.253	0.0415
8	0.373	0.304	0.282	0.285	0.311	0.0425
10	0.323	0.324	0.322	0.325	0.324	0.0013
12	0.333	0.334	0.332	0.335	0.501	0.0013

Table B.53 Browning index of sweet corn with sterilization time of 20 minutes and storage at 40°C

Time(weeks)	Rep1	Rep2	Rep3	Rep4	Avg	SE
0	0.107	0.104	0.130	0.097	0.110	0.0143
1	0.150	0.145	0.124	0.131	0.138	0.0121
2	0.145	0.145	0.134	0.131	0.139	0.0073
3	0.284	0.282	0.240	0.261	0.267	0.0206
4	0.302	0.345	0.422	0.333	0.351	0.0510
5	0.381	0.382	0.379	0.380	0.381	0.0013
6	0.321	0.323	0.319	0.319	0.320	0.0019
8	0.337	0.327	0.326	0.331	0.330	0.0050
10	0.347	0.347	0.346	0.331	0.343	0.0078
12	0.357	0.357	0.356	0.341	0.353	0.0078

Table B.54 Browning index of sweet corn with sterilization time of 20 minutes and storage at 50°C

Time(weeks)	Rep1	Rep2	Rep3	Rep4	Avg	SE
0	0.107	0.104	0.130	0.097	0.110	0.0143
1	0.272	0.274	0.210	0.211	0.242	0.0361
2	0.282	0.289	0.251	0.259	0.270	0.0181
3	0.308	0.310	0.320	0.327	0.316	0.0089
4	0.388	0.378	0.372	0.374	0.378	0.0071
5	0.409	0.402	0.399	0.391	0.400	0.0075
6	0.324	0.311	0.322	0.328	0.321	0.0072
8	0.331	0.329	0.330	0.339	0.332	0.0046
10	0.361	0.369	0.363	0.359	0.363	0.0043
12	0.371	0.379	0.373	0.369	0.373	0.0043

Effect of anti-browning agent on browning inhibition

B.8 Total soluble phenolic content

Determine total soluble phenolic content.

Table B.55 Total phenolic content of sweet corn control sample stored at 30°C

Time(weeks)	Rep1	Rep2	Avg	SE
0	317.46	316.01	316.74	0.0052
3	282.68	301.52	292.10	0.0450
7	262.39	281.96	272.18	0.0465
11	274.71	276.88	275.80	0.0077
20	209.52	218.05	213.79	0.0120
24	187.30	164.33	175.81	0.0100

Table B.56 Total phenolic content of sweet corn with ascorbic acid and storage at 30°C

Time(weeks)	Rep1	Rep2	Avg	SE
0	342.10	378.33	360.22	0.1050
3	369.64	377.61	373.63	0.0583
7	353.70	337.03	345.37	0.1012
11	342.10	341.38	341.74	0.0691
20	253.15	291.31	272.23	0.0200
24	232.63	234.56	233.60	0.0100

Table B.57 Total phenolic content of sweet corn with citric acid and storage at 30°C

Time(weeks)	Rep1	Rep2	Avg	SE
0	323.26	332.68	327.97	0.0300
3	299.35	295.72	297.54	0.0263
7	273.99	275.43	274.71	0.0139
11	264.57	263.12	263.85	0.0195
20	223.05	209.59	216.32	0.0200
24	197.19	196.28	196.73	0.0100

Table B.58 Total phenolic content of sweet corn with sodium erythroate and storage at 30°C ($F_0 = 6$ minutes)

Time(weeks)	Rep1	Rep2	Avg	SE
0	395.72	396.45	396.09	0.0451
3	371.09	354.42	362.76	0.0310
7	321.09	335.58	328.34	0.0248
11	322.54	328.33	325.44	0.0093
20	269.09	241.83	255.46	0.0100
24	245.35	225.98	235.66	0.0200

Table B.59 Total phenolic content of sweet corn with citric acid and sodium erythroate and storage at 30°C ($F_0 = 6$ minutes)

Time(weeks)	Rep1	Rep2	Avg	SE
0	344.28	347.17	345.73	0.0901
3	308.77	339.93	324.35	0.0582
7	357.32	344.28	350.80	0.0327
11	309.49	318.19	313.84	0.0124
20	258.21	281.21	269.71	0.0100
24	237.55	249.96	243.76	0.0100

Table B.60 Total phenolic content of sweet corn control sample stored at 40°C ($F_0 = 6$ minutes)

Time(weeks)	Rep1	Rep2	Avg	SE
0	317.46	316.01	316.74	0.0442
3	317.46	285.58	301.52	0.0681
7	250.80	266.74	258.77	0.0382
11	277.61	268.91	273.26	0.0166
20	187.30	189.61	188.45	0.0202
24	165.08	170.65	167.86	0.0211

Table B.61 Total phenolic content of sweet corn with ascorbic acid and storage at 40°C
($F_0 = 6$ minutes)

Time(weeks)	Rep1	Rep2	Avg	SE
0	342.10	378.33	360.22	0.0710
3	306.59	327.61	317.10	0.0214
7	297.17	318.19	307.68	0.0195
11	336.30	331.96	334.13	0.0747
20	277.10	298.88	287.99	0.0131
24	266.84	272.40	269.62	0.0218

Table B.62 Total phenolic content of sweet corn with citric acid and storage at 40°C
($F_0 = 6$ minutes)

Time(weeks)	Rep1	Rep2	Avg	SE
0	323.26	332.68	327.97	0.0442
3	277.61	254.42	266.02	0.0665
7	268.19	266.01	267.10	0.0212
11	256.30	285.58	270.94	0.0464
20	210.12	226.22	218.17	0.0200
24	197.19	196.28	196.73	0.0100

Table B.63 Total phenolic content of sweet corn with sodium erythroate and storage at 40°C ($F_0 = 6$ minutes)

Time(weeks)	Rep1	Rep2	Avg	SE
0	395.72	396.45	396.09	0.0387
3	310.94	321.81	316.38	0.0184
7	329.06	321.09	325.08	0.0153
11	309.49	325.43	317.46	0.0274
20	261.18	257.69	259.43	0.0414
24	245.35	241.83	243.59	0.0329

Table B.64 Total phenolic content of sweet corn with citric acid and sodium erythrobrate and storage at 40°C ($F_0 = 6$ minutes)

Time(weeks)	Rep1	Rep2	Avg	SE
0	344.28	347.17	345.73	0.0319
3	349.35	294.28	321.82	0.1181
7	301.52	295.72	298.62	0.0170
11	336.30	345	340.65	0.0120
20	258.21	246.49	252.35	0.0192
24	241.00	239.55	240.27	0.0109

Table B.65 Total phenolic content of sweet corn control sample stored at 30°C ($F_0 = 8$ minutes)

Time(weeks)	Rep1	Rep2	Avg	SE
0	350.07	349.35	349.71	0.030
2	309.49	313.12	311.31	0.0086
4	259.49	258.77	259.13	0.0004
6	268.19	259.49	263.84	0.0165
8	243.55	239.2	241.38	0.0078
10	287.03	279.78	283.41	0.0135
12	289.93	291.38	290.66	0.0041
20	266.05	258.519	262.29	0.0101
24	234.55	213.1035	223.83	0.0502

Table B.66 Total phenolic content of sweet corn with ascorbic acid and storage at 30°C ($F_0 = 8$ minutes)

Time(weeks)	Rep1	Rep2	Avg	SE
0	395.00	393.55	394.28	0.0210
2	381.23	382.68	381.96	0.0051
4	369.56	373.26	371.41	0.0091
6	366.01	373.99	370.00	0.0168
8	392.10	401.52	396.81	0.0195
10	309.49	311.67	310.58	0.0060
12	286.30	269.64	277.97	0.0280
20	213.30	220.388	216.84	0.0204
24	229.10	240.0655	234.58	0.0310

Table B.67 Total phenolic content of sweet corn with citric acid and storage at 30°C
($F_0 = 8$ minutes)

Time(weeks)	Rep1	Rep2	Avg	SE
0	339.20	342.1	340.65	0.0360
2	312.39	316.74	314.57	0.0035
4	276.16	272.54	274.35	0.0124
6	270.36	285.58	277.97	0.0267
8	289.93	297.9	293.92	0.0114
10	250.07	247.17	248.62	0.0104
12	258.77	274.71	266.74	0.0284
20	200.13	212.10	206.12	0.0400
24	206.91	208.68	207.80	0.0101

Table B.68 Total phenolic content of sweet corn with sodium erythroate and storage at 30°C ($F_0 = 8$ minutes)

Time(weeks)	Rep1	Rep2	Avg	SE
0	369.64	365.67	367.66	0.0021
2	339.56	347.17	343.37	0.0218
4	345.00	340.98	342.99	0.0006
6	316.01	313.12	314.57	0.0010
8	352.97	347.17	350.07	0.0039
10	292.10	291.37	291.74	0.0047
12	274.71	259.49	267.10	0.0237
20	214.39	208.432	211.41	0.0300
24	188.52	190.148	189.33	0.0202

Table B.69 Total phenolic content of sweet corn with citric acid and sodium erythroate and storage at 30°C ($F_0 = 8$ minutes)

Time(weeks)	Rep1	Rep2	Avg	SE
0	360.94	365.29	363.12	0.0561
2	352.97	356.59	354.78	0.0012
4	319.64	312.45	316.05	0.0214
6	339.92	342.1	341.01	0.0037
8	334.13	358.04	346.09	0.0385
10	290.65	297.9	294.28	0.0073
12	286.30	267.46	276.88	0.0431
20	234.61	226.48	230.55	0.0104
24	209.35	204.562	206.95	0.0113

Table B.70 Total phenolic content of sweet corn control sample stored at 40°C
($F_0 = 8$ minutes)

Time(weeks)	Rep1	Rep2	Avg	SE
0	350.07	349.35	349.71	0.0023
2	285.58	287.75	286.67	0.0056
4	248.76	250.8	249.78	0.0052
6	237.75	247.51	242.63	0.0207
8	276.16	278.33	277.25	0.0055
10	239.20	243.55	241.38	0.0098
12	264.57	271.81	268.19	0.0158
20	241.55	223.584	232.57	0.0109
24	213.54	216.597	215.07	0.0502

Table B.71 Total phenolic content of sweet corn with ascorbic acid and storage at 40°C
($F_0 = 8$ minutes)

Time(weeks)	Rep1	Rep2	Avg	SE
0	395.00	393.55	394.28	0.0010
2	327.61	331.23	329.42	0.0087
4	342.83	339.93	341.38	0.0029
6	352.97	355.14	354.06	0.0062
8	371.81	362.39	367.10	0.0145
10	281.97	273.26	277.62	0.0138
12	294.28	281.23	287.76	0.0215
20	252.80	240.0655	246.43	0.0200
24	268.60	255.8075	262.20	0.0301

Table B.72 Total phenolic content of sweet corn with citric acid and storage at 40°C
($F_0 = 8$ minutes)

Time(weeks)	Rep1	Rep2	Avg	SE
0	339.20	342.1	340.65	0.0112
2	300.80	287.75	294.28	0.0323
4	250.07	243.55	246.81	0.0179
6	270.36	269.63	270.00	0.0063
8	297.17	283.41	290.29	0.0337
10	248.62	247.9	248.26	0.0059
12	271.09	266.74	268.92	0.0138
20	230.66	229.21	229.93	0.0400
24	213.70	218.94	216.32	0.0210

Table B.73 Total phenolic content of sweet corn with sodium erythroate and storage at 40°C ($F_0 = 8$ minutes)

Time(weeks)	Rep1	Rep2	Avg	SE
0	369.64	365.67	367.66	0.0340
2	297.17	298.62	297.90	0.0090
4	315.29	300.45	307.87	0.0221
6	312.39	310.94	311.67	0.0037
8	325.43	323.26	324.35	0.0026
10	322.54	310.22	316.38	0.0171
12	252.25	269.64	260.95	0.0389
20	240.27	223.059	231.66	0.0301
24	214.39	215.745	215.07	0.0234

Table B.74 Total phenolic content of sweet corn with citric acid and sodium erythroate and storage at 40°C ($F_0 = 8$ minutes)

Time(weeks)	Rep1	Rep2	Avg	SE
0	360.94	365.29	363.12	0.0341
2	358.04	352.25	355.15	0.0196
4	312.39	309.49	310.94	0.0129
6	316.74	316.01	316.38	0.0088
8	331.96	348.62	340.29	0.0245
10	312.39	318.19	315.29	0.0039
12	262.39	255.14	258.77	0.0202
20	234.61	230.133	232.37	0.0112
24	209.35	208.215	208.78	0.0109

Table B.75 DMHF content of sweet corn control sample stored at 30°C ($F_0 = 6$ minutes)

Time(weeks)	Rep1	Rep2	Avg	SE
0	0.86	0.80	0.83	0.0424
3	0.76	0.81	0.79	0.0354
7	0.39	0.53	0.46	0.0990
11	0.61	0.59	0.60	0.0141
20	0.59	0.50	0.54	0.0689
24	0.63	0.52	0.57	0.0762

Table B.76 DMHF content of sweet corn with ascorbic acid and storage at 30°C ($F_0 = 6$ minutes)

Time(weeks)	Rep1	Rep2	Avg	SE
0	0.81	0.78	0.80	0.0212
3	0.90	0.90	0.90	0.0000
7	0.45	0.41	0.43	0.0283
11	0.57	0.47	0.52	0.0707
20	0.58	0.41	0.49	0.1199
24	0.53	0.43	0.48	0.0689

Table B.77 DMHF content of sweet corn with citric acid and storage at 30°C ($F_0 = 6$ minutes)

Time(weeks)	Rep1	Rep2	Avg	SE
0	0.83	0.81	0.82	0.0141
3	0.81	0.96	0.89	0.1061
7	0.40	0.43	0.42	0.0212
11	0.60	0.51	0.56	0.0636
20	0.65	0.62	0.63	0.0225
24	0.67	0.64	0.66	0.0229

Table B.78 DMHF content of sweet corn with sodium erythroate and storage at 30°C ($F_0 = 6$ minutes)

Time(weeks)	Rep1	Rep2	Avg	SE
0	0.79	0.84	0.82	0.0354
3	0.84	0.98	0.91	0.0990
7	0.41	0.45	0.43	0.0283
11	0.47	0.52	0.50	0.0354
20	0.46	0.48	0.47	0.0146
24	0.51	0.58	0.54	0.0523

Table B.79 DMHF content of sweet corn with citric acid and sodium erythroate and storage at 30°C ($F_0 = 6$ minutes)

Time(weeks)	Rep1	Rep2	Avg	SE
0	0.79	0.80	0.80	0.0071
3	0.86	0.89	0.89	0.0354
7	0.58	0.58	0.58	0.0071
11	0.58	0.54	0.54	0.0636
20	0.56	0.57	0.57	0.0107
24	0.62	0.62	0.62	0.0057

Table B.80 DMHF content of sweet corn control sample stored at 40°C ($F_0 = 6$ minutes)

Time(weeks)	Rep1	Rep2	Avg	SE
0	0.86	0.80	0.83	0.0424
3	0.75	0.74	0.75	0.0071
7	0.57	0.55	0.56	0.0141
11	0.66	0.63	0.65	0.0212
20	0.64	0.58	0.61	0.0427
24	0.67	0.62	0.64	0.0387

Table B.81 DMHF content of sweet corn with ascorbic acid and storage at 40°C ($F_0 = 6$ minutes)

Time(weeks)	Rep1	Rep2	Avg	SE
0	0.81	0.78	0.80	0.0212
3	0.98	0.89	0.94	0.0636
7	0.51	0.53	0.52	0.0141
11	0.67	0.62	0.65	0.0354
20	0.62	0.60	0.61	0.0106
24	0.57	0.55	0.56	0.0093

Table B.82 DMHF content of sweet corn with citric acid and storage at 40°C ($F_0 = 6$ Minutes)

Time(weeks)	Rep1	Rep2	Avg	SE
0	0.83	0.81	0.82	0.0141
3	0.95	0.83	0.89	0.0849
7	0.43	0.47	0.45	0.0283
11	0.61	0.57	0.59	0.0283
20	0.69	0.55	0.62	0.0977
24	0.71	0.53	0.62	0.1267

Table B.83 DMHF content of sweet corn with sodium erythroate and storage at 40°C ($F_0 = 6$ minutes)

Time(weeks)	Rep1	Rep2	Avg	SE
0	0.79	0.84	0.82	0.0354
3	0.95	0.83	0.89	0.0849
7	0.54	1.20	0.87	0.4667
11	0.87	0.71	0.79	0.1131
20	0.50	0.56	0.53	0.0460
24	0.55	0.59	0.57	0.0303

Table B.84 DMHF content of sweet corn with citric acid and sodium erythroate and storage at 40°C ($F_0 = 6$ minutes)

Time(weeks)	Rep1	Rep2	Avg	SE
0	0.79	0.80	0.80	0.0071
3	0.76	0.75	0.75	0.0141
7	0.43	0.47	0.47	0.0566
11	0.66	0.58	0.58	0.1202
20	0.60	0.59	0.59	0.0173
24	0.66	0.65	0.65	0.0223

Table B.85 DMHF content of sweet corn control sample stored at 30°C ($F_0 = 8$ minutes)

Time(weeks)	Rep1	Rep2	Avg	SE
0	1.00	1.00	1.00	0.0000
2	1.01	0.97	0.99	0.0283
4	0.95	1.01	0.98	0.0424
6	1.19	0.96	1.08	0.1626
8	1.15	1.34	1.25	0.1344
10	1.42	1.70	1.56	0.1980
12	1.30	1.29	1.30	0.0071
20	1.69	1.68	1.69	0.0071
24	1.72	1.74	1.73	0.0141

Table B.86 DMHF content of sweet corn with ascorbic acid and storage at 30°C ($F_0 = 8$ minutes)

Time(weeks)	Rep1	Rep2	Avg	SE
0	0.81	0.74	0.78	0.0495
2	0.95	0.96	0.96	0.0071
4	0.98	1.07	1.03	0.0636
6	1.06	1.14	1.10	0.0566
8	1.06	1.44	1.25	0.2687
10	1.55	1.31	1.43	0.1697
12	1.31	1.60	1.46	0.2051
20	1.60	1.42	1.51	0.1294
24	1.59	1.44	1.51	0.1075

Table B.87 DMHF content of sweet corn with citric acid and storage at 30°C ($F_0 = 8$ minutes)

Time(weeks)	Rep1	Rep2	Avg	SE
0	0.89	0.93	0.91	0.0283
2	1.09	1.04	1.07	0.0354
4	0.85	0.83	0.84	0.0141
6	0.74	0.72	0.73	0.0141
8	1.05	1.43	1.24	0.2687
10	1.19	1.45	1.32	0.1838
12	1.19	1.45	1.32	0.1838
20	1.49	1.53	1.51	0.0341
24	1.52	1.53	1.52	0.0023

Table B.88 DMHF content of sweet corn with sodium erythroate and storage at 30°C $(F_0 = 8 \text{ minutes})$

Time(weeks)	Rep1	Rep2	Avg	SE
0	0.76	0.76	0.76	0
2	1.00	0.79	0.90	0.1485
4	1.08	1.02	1.05	0.0424
6	0.96	1.19	1.08	0.1626
8	1.42	1.44	1.43	0.0141
10	1.29	1.64	1.47	0.2475
12	1.28	1.31	1.30	0.0212
20	1.28	1.27	1.27	0.0054
24	1.38	1.36	1.37	0.0107

Table B.89 DMHF content of sweet corn with citric acid and sodium erythroate andstorage at 30°C ($F_0 = 8 \text{ minutes}$)

Time(weeks)	Rep1	Rep2	Avg	SE
0	0.89	0.79	0.84	0.0707
2	0.93	1.09	1.01	0.1131
4	0.89	0.99	0.94	0.0707
6	1.38	1.57	1.48	0.1344
8	1.36	1.33	1.35	0.0212
10	1.58	1.40	1.49	0.1273
12	1.29	1.29	1.29	0.0000
20	1.58	1.37	1.47	0.1419
24	1.53	1.34	1.44	0.1328

Table B.90 DMHF content of sweet corn control sample stored at 40°C ($F_0 = 8 \text{ minutes}$)

Time(weeks)	Rep1	Rep2	Avg	SE
0	1.00	1.00	1.00	0.0000
2	0.91	1.10	1.01	0.1344
4	0.86	0.81	0.84	0.0354
6	0.68	0.68	0.68	0.0000
8	1.60	1.61	1.61	0.0071
10	2.00	1.68	1.84	0.2263
12	1.29	1.30	1.30	0.0071
20	1.74	1.72	1.73	0.0141
24	1.77	1.79	1.78	0.0141

Table B.91 DMHF content of sweet corn with ascorbic acid and storage at 40°C ($F_0 = 8$ minutes)

Time(weeks)	Rep1	Rep2	Avg	SE
0	0.81	0.74	0.78	0.0495
2	0.86	0.87	0.87	0.0071
4	1.02	1.02	1.02	0.0000
6	0.62	0.83	0.73	0.1485
8	1.34	1.34	1.34	0.0000
10	1.61	1.32	1.47	0.2051
12	1.34	1.32	1.33	0.0141
20	1.64	1.19	1.42	0.3202
24	1.63	1.20	1.41	0.3036

Table B.92 DMHF content of sweet corn with citric acid and storage at 40°C ($F_0 = 8$ minutes)

Time(weeks)	Rep1	Rep2	Avg	SE
0	0.89	0.93	0.91	0.0283
2	0.88	0.80	0.84	0.0566
4	0.90	1.01	0.96	0.0778
6	0.88	0.97	0.93	0.0636
8	1.14	1.27	1.21	0.0919
10	1.72	1.42	1.57	0.2121
12	1.72	1.42	1.57	0.2121
20	1.53	1.58	1.56	0.0355
24	1.57	1.57	1.57	0.0037

Table B.93 DMHF content of sweet corn with sodium erythroate and storage at 40°C $(F_0 = 8 \text{ minutes})$

Time(weeks)	Rep1	Rep2	Avg	SE
0	0.76	0.76	0.76	0
2	1.05	0.92	0.99	0.0919
4	0.98	1.02	1.00	0.0283
6	1.25	0.60	0.93	0.4596
8	1.28	1.27	1.28	0.0071
10	1.65	1.67	1.66	0.0141
12	1.29	1.30	1.30	0.0071
20	1.31	1.33	1.32	0.0107
24	1.41	1.37	1.39	0.0322

Table B.94 DMHF content of sweet corn with citric acid and sodium erythroate andStorage at 40°C ($F_0 = 8 \text{ minutes}$)

Time(weeks)	Rep1	Rep2	Avg	SE
0	0.89	0.79	0.84	0.0707
2	0.98	0.99	0.99	0.0071
4	0.98	0.91	0.95	0.0495
6	1.41	1.45	1.43	0.0283
8	1.55	1.56	1.56	0.0071
10	1.73	1.64	1.69	0.0636
12	1.27	1.31	1.29	0.0283
20	1.62	1.41	1.52	0.1455
24	1.58	1.35	1.46	0.1587

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