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Storage of Sweet Corn (*Zea mays saccharata*, L) on Various Temperatures and its Effects on Save Age and Physicochemical Quality

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Abstract. Sweet corn is classified as a horticultural commodity that is very easily damaged. Damage quickly occurs after the harvest which causes a decrease in quality. The purpose of this study was to determine the effect of cooling temperature on shelf life and the physicochemical quality of sweet corn. The study used a Randomized Block Design (RBD) with cold storage temperature treatment namely: 1^{o}C, 5^{o}C, 9^{o}C, and room temperature 27^{o}C. Each treatment was repeated three times as a group. Sweet corn that has been stored is then observed: shelf life, weight loss, starch content, total dissolved solids, and reducing sugar content. The results showed that storage of sweet corn at 1^{o}C was the best cooling temperature treatment based on decreasing weight loss, 2.68% lower, the longest shelf life of 80 days, total dissolved solids of 23.33 brix, higher reducing sugar content of 5.18 %, and the lowest starch content is 2.49%. This research concludes that the storage temperature of 1^{o}C can extend the shelf life and physicochemical quality of sweet corn

INTRODUCTION

Sweet corn (*Zea mays* (L.) var. *saccharata*) is a plant that is cultivated for human consumption and is a raw material for processed food industries around the world. Sweet corn is popular among consumers because of its unique, delicious, and sweet taste. Corn contains carbohydrates that are quite high, which is about 74.26 grams per 100 grams, and is mostly concentrated in the endosperm. The carbohydrate content in corn kernels consists of amylose and amylopectin, which are composed of sucrose sugar chains. The starch content in corn kernels contributes greatly to the total energy availability of corn kernels [1]. Corn contains other macronutrients such as fat and protein, which of course are needed by the body. Corn fat consists of two types of fatty acids, namely saturated fatty acids and unsaturated fatty acids. Saturated fatty acids consist of palmitic and stearic fatty acids, while unsaturated fatty acids consist of oleic and linoleic fatty acids which are mostly concentrated in the institution.

Sweet corn plays an important role in the human diet due to its health-promoting nutritional content. The nutritional value of sweet corn was related to water content (72.7%) and total solids content (27.3%). The solid portion includes hydrocarbons (81%), proteins (13%), lipids (3.5%), and others (2.5%). Complete information can be seen in table 1. Starch is the dominant hydrocarbon component [2].

TABLE 1 Chemical and Nutritional Content Sweet corn (*Zea mays* (L.) var. *saccharata*)

Nutritional content	Unit	Content per 100 g
Water	g	10,37
Energy	kkal	465
Protein	g	9,42
Fat	g	4,74
Carbohydrate	g	74,26

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Nutritional content	Unit	Content per 100 g
Calcium	mg	7
Iron	mg	2,71
Magnesium	mg	127
Phosphor	mg	210
Potassium	mg	287
Tamin	mg	0,385
Riboflavin	mg	0,201
Niacin	mg	3,627

The yellow sweet corn variety is the most commonly recognized. Unlike other varieties of corn which are harvested at full maturity, sweet corn is picked when it is not yet ripe, so it is a perishable vegetable. The shelf life of sweet corn is one of the shortest among fruits and vegetables [3]. The damage to freshly harvested maize is caused by various biological factors such as respiration, changes in composition (related to color, texture, taste, and nutritional value), physiological disturbances, and pathological damage. Environmental factors (external) include temperature, relative humidity, atmospheric composition (O_2) and (CO_2), and airflow velocity [4](Bello, Badejo, 2017).

The main indicator of sweet corn quality is determined by the sugar content or level of sweetness. The higher the sugar content, the better the quality [5,6]. Sweetness is determined not only by genetic factors but also by variety, harvest time and post-harvest handling. The shelf life of sweet corn is relatively short especially when stored at room temperature in tropical countries (28-32 °C). Damage to sweet corn can be indicated by a decrease in sugar content [7]x. According to Xiaolong and Yunfei, about 60% of sugar is lost at 30 ºC and 6% at 0 ºC [8].

The process of respiration is strongly influenced by high environmental temperatures because it causes an increase in the respiration process in sweet corn after harvesting. Physical quality (texture, color, weight loss) and chemical (sugar, protein, carbohydrate, and moisture content) in a short period of time after harvest is a major problem in post-harvest handling of this commodity [9]. Rapid loss of water content and conversion of sugar to starch immediately after harvest, especially at room temperature, have long been major postharvest problems for fresh corn. These types of damage will affect the freshness of sweet corn. One of the ways to prevent quality degradation is by cold temperature treatment [10].

The sweet taste of sweet corn will decrease within 48 hours after harvest [11]. Therefore, storage must be done in a cooled room with a temperature of 1 °C - 4 °C so that it can last up to 4 days. Geetha *et al*, reported that the shelf life of sweet corn is very limited because the sweetness and soft textures are lost rapidly [12]. Sweet corn can last for a week or more if stored at 0 °C and 90-98% relative humidity immediately after harvest. This is in line with what Seminis reported, that the maximum quality of sweet corn can be maintained if it is cooled to a temperature of around 32°F (0ºC) within one hour after harvest [13]. Riad *et al*. reported that storage in a controlled atmosphere (CA) is beneficial in maintaining the visual quality of fresh sweet corn kernels, besides that it can last 10 days if stored at 5°C because the loss of sugar and taste can be reduced, compared to normal air storage [14]. To prevent deterioration, it is essential to chill sweet corn as soon as possible after harvesting and to keep it cool while it is marketing. This research was conducted to analyze the effect of cold temperature on shelf life and physicochemical properties of sweet corn.

RESEARCH METHODS

This research was carried out at the Agrotechnology Study Program Laboratory, Faculty of Agriculture, Muslim University of Indonesia (Figure 1). The study used a Randomized Block Design (RBD) with cold storage temperature treatment namely: 1ºC, 5ºC, 9ºC, and room temperature 27ºC. Each treatment was repeated three times as a group. Sweet corn that has been stored is then observed: shelf life, weight loss, starch content, total dissolved solids, and reducing sugar content.

FIGURE 1. The step of methodology in this study

Materials and Tools

The materials used in this study were: sweet corn, Bonanza variety, tissue, equates, Na_2CO_3, Luff-Schoorl reagent. KI 20%, H_2SO_4 26.5%, Na-Thiosulfate 0.0595 N, Polypropylene plastic. $CuSO_4.5H_2O$, $Na_2CO_3.10H_2O$, $C_6H_8O_7$, filter paper, white cloth, aluminum foil.

The tools used include scale, basin, cutting knife, glass funnel, thermometer, refrigerator, blender, pipette, Erlenmeyer, burette, watch glass, measuring flask, oven, measuring cup, glass stirrer, and hand refractometer.

Research design

The research was conducted using a randomized block design (RBD) method. The treatment tested was the storage temperature with four levels: 1ºC, 5ºC, 9ºC, and ± 27ºC (room temperature). Each treatment was repeated three times. Data analyzed by ANOVA. If F count shows a significant effect ($P < 5\%$) at the 95% test level then it is followed by the Honest Significant Difference test (HSD) to find out the differences between treatments.

Research Implementation

Sampling Location, Harvesting of sweet corn from farmers' planting locations in Pakatto Village, Bontomarannu District, Gowa Regency, South Sulawesi. Corn is harvested at 65 days after planting or in the final phase of milk cooking. Corn cobs of uniform size were selected and then thrown away. The cobs of sweet corn are washed with ice water (pre-cooling), then dried. Sweet corn cobs are packed with polypropylene (PP) plastic containing three cobs each. Packaged corn is stored in a refrigerator by the treatment temperature, namely 1ºC, 5ºC, 9ºC, and room temperature ± 27ºC.

Observation

Observations were made at the end of storage when sweet corn cobs began to show signs of organoleptic visible damage. The parameters observed were:

Weight Loss (%) The weight loss of sweet corn is calculated according to the formula:

$$\text{Weight loss} = \frac{(Wa - Wb)}{Wa} x\ 100\%$$

Description of the equation:

Wa = initial weight of material before storage

Wb = final weight of material after storage

Total Dissolved Solids (Brix), was measured using ANTAGO's N-1 model hand refractometer; Reducing sugar content using the Luff-Schoorl method; Starch content, a total of 300 grams of corn was homogenized with 200 ml of distilled water in a blender for ± 1 minute then the mixture was filtered through a piece of white cloth, the cloudy liquid was collected in a 500 ml beaker. The liquid was added with 200 ml of distilled water, shake then the mixture was allowed to settle. The liquid on top of it is decanted. Starch is suspended again with 200 ml of distilled water. This decantation work was repeated with 100 ml of 95% ethanol and then decanted again. Filter through a Buchner funnel. Starch is dried by spreading at room temperature, after drying and then weighed; Shelf life (days) is calculated from the first day of storage until the sweet corn is damaged (wrinkled or moldy).

RESULTS AND DISCUSSION

The results of observations and analysis in this study showed that the control and packaged sweet corn resulted in significantly different weight loss, while for the type of paper packaging it was significantly different with temperature. This difference is expected to reduce the nutritional content and mass weight of corn depending on the temperature.

Weight Loss

ANOVA results (α = 0.05) showed that storage temperature treatment did not significantly affect weight loss (P> 0.05). The weight loss histogram is presented in Figure 2. The average weight loss ranging from 2.68 - 7.34% during storage of sweet corn. Storage of sweet corn at various cold temperatures and room temperature did not differ in the reduction of weight loss. Weight loss in sweet corn during storage with various types of packaging temperatures shown in Figure 2. shows that the longer the storage time, the higher the weight loss that occurs [15].

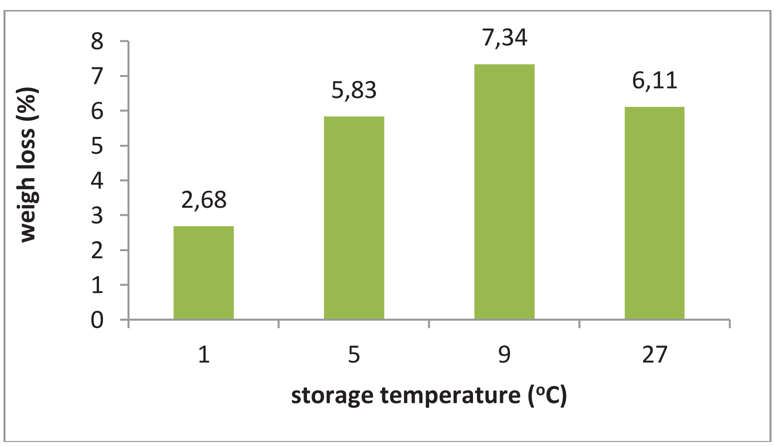

FIGURE 2. Weight loss of sweet corn

Total Dissolved Solids

ANOVA results (α = 0.01) showed that the storage temperature treatment had a very significant effect (P <0.01) on the total dissolved solids of sweet corn. The mean total dissolved solids are presented in Figure 3.

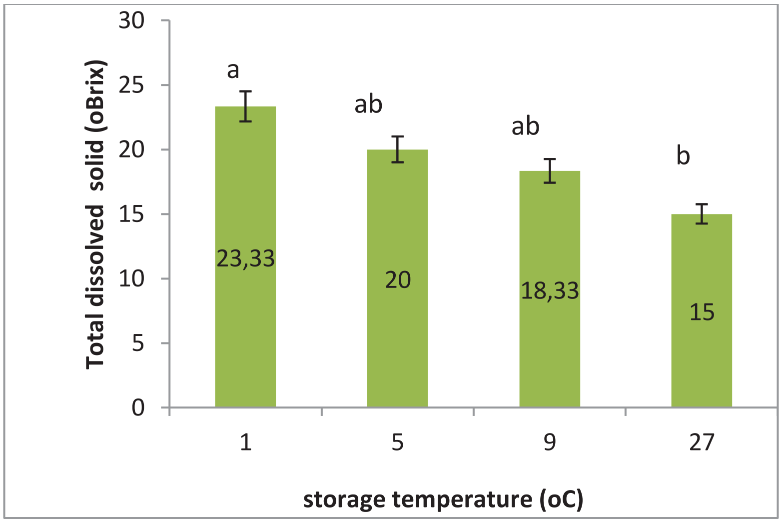

FIGURE 3. Total dissolved solids of sweet corn after storage

The results of the HSD test (α = 0.05) in Figure 3 show that storage at 1 ºC has the highest total dissolved solids, namely 23.33 ºBrix but not significantly different from sweet corn stored at 5 ºC and 9 ºC, respectively 20º Brix and 18.33º Brix. . Sweet corn stored at 27º C contained the lowest total solids at 15 º Brix. Generally, at lower temperatures, the quality of sweet corn can be maintained. Increasing the temperature speeds up not only the respiration process itself but also other processes that are responsible for most of the sugar loss. Furthermore, the sugar is converted into starch or other polysaccharides, hydrolyzed by dilute acids during storage due to high temperatures [16] (Panchal *et al*., 2017). About four times as much sugar is lost at 10ºC (50ºF) than 0ºC (32ºF). Pericarp hardening can be minimized by rapid cooling at 0ºC (32ºF) [17](Bakry *et al*., 2015).

Total dissolved solids in plants are mainly the sugars sucrose, fructose, and glucose. A decrease in the level of Total Dissolved Solids (TDS) measured using a refractometer will be in line with a decrease in the quality value, in this case, the sweetness level measured organoleptically, and vice versa. The low TDS level of sweet corn at a storage temperature of 27 ºC is because this temperature will accelerate respiration so that the decrease in total dissolved solids will be even faster. This is because the total dissolved solids in the product are used during the respiration process.

Studies on sweet corn show that 60% of sugar can be lost in 24 hours if stored at 30 ºC. This figure is four times higher than that of 0 ºC storage [18]. Corn will have satisfactory culinary quality for a maximum of 6-8 days at 0 ºC, 3-4 days at 5 degrees Celsius, and 2 days at 10 ºC [19] (Geetha *et al*., 2017b). To maintain its best quality, sweet corn is refrigerated to near 0 ºC immediately after harvest and stored in the refrigerator until it reaches consumers. This is by the research of Xie *et al*, that the quality of sweet corn stored at 0 °C is the best [20].

Reducing Sugar

ANOVA results (α = 0.05) showed that storage temperature treatment had no significant effect (P> 0.05) on reducing sugar levels. Reducing sugar levels can be seen in Figure 4.

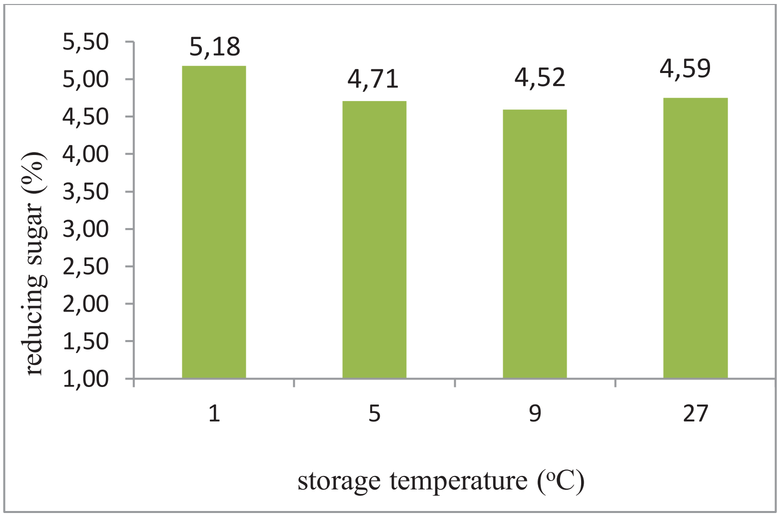

FIGURE 4. Reducing sugar content of sweet corn after storage

Figure 4 shows the storage of sweet corn at 1°C produces a reducing sugar of 5.18%, while sweet corn stored at 5°C, 9°C, and 27°C is 4.71%, 4.52%, and 4.59% respectively. This shows that there is no difference in reducing the sugar content of sweet corn after storage at both cold and room temperature. Murdiati and Sutrisno state that sweet corn stored in normal air at room temperature has the lowest reducing sugar content [21]. In the process of respiration reducing sugars (glucose and fructose) are broken down into sucrose and starch. The more respiration increases, the reducing sugar content will decrease, while the sweet corn starch content increases. About four times as much sugar was lost at 10°C (50°F) than at 0°C (32°F). The heat of respiration will raise the temperature by several degrees celsius on the inside of a large pile of corn [16].

Starch

ANOVA results (α = 0.01) showed that the storage temperature treatment had a very significant effect ($P < 0.01$) on the levels of sweet corn starch. The starch content of sweet corn after storage can be seen in Figure 5.

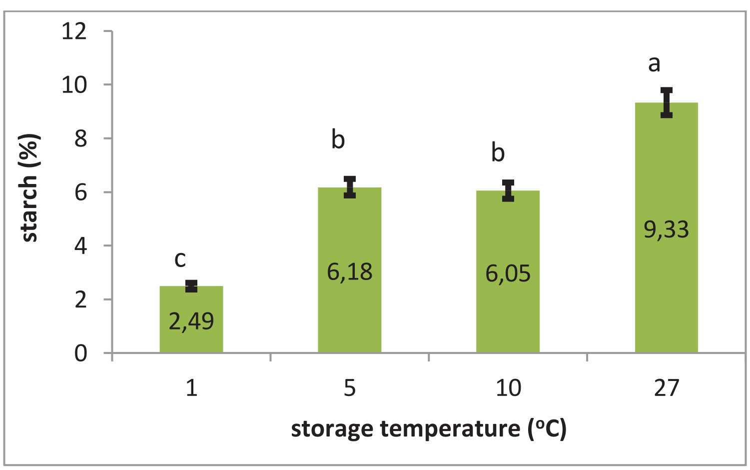

FIGURE 5. Starch content of sweet corn after storage

The HSD test (α = 0.05) in Figure 5 shows that sweet corn stored at 27°C has the highest starch content, namely 9.33%, which is significantly different from the storage temperature 1°C with the lowest starch content 2.49%, and significantly different from temperature 5.°C and 9°C 6.18% and 6.05%, respectively. This is in line with the results of the Total Dissolved Solids (TDS) measurement in Figure 3, that the highest TDS is at a storage temperature of 1°C

(23.33 ºBrix). At 1ºC storage, it can suppress the respiration rate so that it slows down the conversion of sugar to starch, on the other hand, the temperature of 27ºC shows the highest starch content of 9.33% with a reducing sugar content of 15ºBrix.

According to Seminis, the sugar in the seeds will begin to be converted into starch after the cobs are harvested or after the milk cooking stage [22]. If left on the plant, it will reduce the sweetness and tenderness. The higher the temperature the faster this process occurs.

Research results by Geetha *et al*. stated that the storage temperature of 0°C is the optimum storage temperature for sweet corn with its shells [12]. However, the conversion of sugar to starch cannot be completely prevented at this temperature even though it is slowing down compared to other storage temperatures tested. Therefore, the study of sweet corn packaging was carried out only at 0°C with the skin intact. During storage of sweet corn cobs at these temperatures in different packaging systems, the starch content was found to increase with the length of storage.

In cold temperature treatment, especially at 1ºC, it can inhibit the activity of the UDPG-Fructose transglycosylase enzyme and the UDPG starch-glucosyl-transferase enzyme which can inhibit the conversion of sugar into starch in sweet corn. The reaction speed will decrease by 2 times with every 10ºC temperature drop, and the enzyme will work optimally at 25ºC-35ºC. The process of synthesizing starch from simple sugars is an enzymatic reaction, so the oxidation of simple sugars to starch is inhibited and the starch content is less [23]. The results of the Calvo-Brenes, & O´Hare study showed that color and starch content were not affected by storage at 4 °C for up to 15 days [24]. At low temperatures, the conversion rate of sugar to starch decreases [25].

According to Rubatzky and Yamaguchi, the respiration rate of sweet corn is quite high and the conversion of sugar into starch can take place quickly [26]. Approximately 48 hours after harvest, the sucrose in sweet corn kernels will slowly turn into unsweetened dextrins. SU gene (the gene that causes sweetness in corn) works slowly and inefficiently so that the sucrose sugar will quickly turn into dextrins, then turn again into starch.

Shelf Life

ANOVA results (α = 0.01) showed that storage temperature had a very significant effect (P <0.01) on the shelf life of sweet corn. The average shelf life of sweet corn can be seen in Figure 6. The HSD test (α = 0.05) in Figure 6 shows storage at 1ºC, the shelf life of sweet corn reaches 80 days and is significantly different from storage at 9ºC with a shelf life of 49 days, and the lowest shelf life is 13 days at 27ºC. The packaging of freshly harvested corn in plastic film stored in tropical conditions (temperature 28-30 °C and relative humidity 70-80%) has been reported by Oluwalana *et al.* (2017) significantly reduced the water content and appearance and toughness of the corn kernels [27]. However, this method did not show a significant effect on the retention of sugar content and the prolongation of the storage period of fresh maize at room temperature [28]. The combination of plastic film packaging and storage at a low temperature of 5-10 °C has been reported by Bello and Badejo to significantly maintain sweetness and other nutritional composition for 8 days [4]. Sweet corn is sold for two days under four different conditions: (A) 4°C with polyvinyl chloride stretch membrane packaging, (B) 4 °C without packaging, (C) 20°C with polyvinyl chloride membrane packaging, (D) 20°C without packaging. The results showed that the optimal retail conditions were below 4°C with polyvinyl chloride membrane packaging [29].

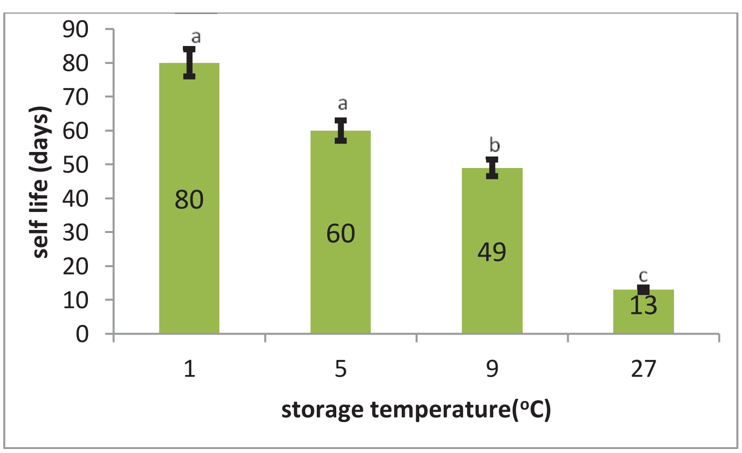

FIGURE 6. The shelf life of sweet corn

At 27ºC (room temperature) the ripening process is faster than the refrigerator temperature. This is because temperature greatly affects respiration activities so that products that are treated at room temperature experience deterioration/decay faster. Damage to sweet corn is indicated by a change in appearance, namely wrinkled seeds. This is an indicator that the withering process occurs as a result of the loss of water from the tissues due to the metabolic process of sweet corn during storage. Overall, increasing the temperature causes an exponential increase in respiration, and will generate heat. Each 10ºC (18°F) temperature increase, the respiration rate increases 2 to 3 times [30]. The faster the respiration rate, the shorter the shelf life and conversely the slower the respiration rate, the longer the shelf life [31], meanwhile according to Xie *et al*, the higher the storage temperature, the higher the respiration rate [20]. The respiration rate at 30°C is about 10 times higher than at 0°C. With increasing storage temperature, sensory evaluation, soluble sugar, vitamin C, and soluble protein levels decreased gradually, but the weight loss of sweet corn increased.

CONCLUSIONS

The results showed that the storage temperature of 1ºC could extend the shelf life and physicochemical properties of sweet corn. The average weight loss ranging from 2.68 - 7.34% during storage of sweet corn. Storage of sweet corn at various cold temperatures and room temperature did not differ in the reduction of weight loss. Sweet corn stored at 27ºC contained the lowest total solids at 15º Brix. Generally, at lower temperatures, the quality of sweet corn can be maintained. Increasing the temperature speeds up not only the respiration process itself but also other processes that are responsible for most of the sugar loss.The low TDS level of sweet corn at a storage temperature of 27 ºC is because this temperature will accelerate respiration so that the decrease in total dissolved solids will be even faster. This is because the total dissolved solids in the product are used during the respiration process. In the process of respiration reducing sugars (glucose and fructose) are broken down into sucrose and starch. The more respiration increases, the reducing sugar content will decrease, while the sweet corn starch content increases. About four times as much sugar was lost at 10ºC (50ºF) than at 0ºC (32ºF). The results of the Total Dissolved Solids (TDS) measurement in Figure 3, that the highest TDS is at a storage temperature of 1 ºC (23.33 ºBrix). At 1 ºC storage, it can suppress the respiration rate so that it slows down the conversion of sugar to starch, on the other hand, the temperature of 27 ºC shows the highest starch content of 9.33% with a reducing sugar content of 15ºBrix.Therefore, the study of sweet corn packaging was carried out only at 0°C with the skin intact. During storage of sweet corn cobs at these temperatures in different packaging systems, the starch content was found to increase with the length of storage. Therefore, the study of sweet corn packaging was carried out only at 0°C with the skin intact. During storage of sweet corn cobs at these temperatures in different packaging systems, the starch content was found to increase with the length of storage.

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