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EFFECT OF PRE-TREATMENT ON PHYSICAL PROPERTIES, ASCORBIC ACID AND β-CAROTENE CONTENT OF FROZEN SWEET CORN KERNELS HIBRIMAS (*Zea mays* var *Saccharata* BAILEY) VARIETY

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ABSTRACT

The main objective of this study is to investigate the best pre-treatment based on physical properties, ascorbic acid and β-carotene content of frozen sweet corn kernels of the Hibrimas variety. Five types of pre-treatments being studied: water blanching, steam blanching, 0.5% citric acid blanching, 2.0% sodium chloride blanching and 1.0% sodium metabisulfite blanching. It was discovered that sodium metabisulfite blanching can improve texture of frozen corn kernels while citric acid blanching play vital role in colour and total soluble solids retention. pH value is more stable after subjected to steam pre-treatment. Chemical pre-treatments were outweighing physical pre-treatments in ascorbic acid retention. There were no significant effects showed by pre-treatments on storage weight loss and β-carotene content. Citric acid pre-treatment was suggested to be the best pre-treatment due to its high colour and total soluble content.

Key words: Pre-treatment, sweet corn, physicochemical properties, ascorbic acid, β-carotene

INTRODUCTION

Hibrimas is the new sweet corn hybrid developed by *MARDI* in cooperation with Green World Genetics (GWG) and Tropical Fruit Network (TFNet) in 2008. Hibrimas has the characteristics of wind resistance, faster maturity rate of just 68 days and uniform kernel size nicely arranged on the cob thus benefiting the farmers since it makes was able to produce nearly 90% yield valued at RM 7000 to RM 8000 per acre for each season. Hibrimas has good market value since it is high in demand. However, for now Hibrimas is mostly sold for fresh consumption and lack of processed product since it is still considered as a new sweet corn variety (Aziz, 2010).

One of the most demanded processed product from sweet corn is frozen kernels. Frozen kernels can be defined as the product produced from fresh, whole and succulent kernels after dehusking, washing, blanching, removing from corn cobs and quick freezing into -18ºC (FAO & WHO, 1994). During frozen storage, frozen kernels have lesser nutrient loss compare to fresh kernels. According to Favell (1998) it is possible for the nutrient content of fresh vegetables continue to fall and even lower than frozen vegetables during retail distribution and storage. Next, there is also less nutrient loss incurred in cooking of frozen vegetables due to this partially cooked product needs shorter cooking time compared to fresh vegetables. Besides having better nutrient keeping quality, frozen kernels also suitable to be produced by using sweet corn of the Hibrimas variety since it has hard kernels that are

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not easily crushed or shrink during freezing process (MARDI, 2011).

Frozen vegetable products require pre-treatments to inactivate enzymes which can cause enzyme-induced oxidation and deteriorate the quality of the vegetables. It can also preserve vitamins, colour, texture and flavour of the vegetables. Some enzymes can survive in freezing temperature and continue to decay vegetables even in frozen condition. Thus, pre-treating sweet corn prior to production of frozen kernels is essential to ensure food safety and to have better organoleptic characteristics of the end product (Martinez-Romero, 2003). Pre-treatments can be divided into 2 major groups, which are physical and chemical pre-treatments. Physical pre-treatment refers to methods that do not involve any chemicals such as hot water blanching, steam blanching and microwave heating. On the other hand, boiling or dipping solutions of citric acid, sodium chloride, sodium metabisulfite, sodium chloride-lactic acid or calcium chloride-lactic acid are examples of chemical pre-treatments (Severini *et al*., 2003).

Up until now, there has been no study regard effect of pre-treatments on the frozen sweet corn of the Hibrimas variety. Thus, this study is carried out to investigate the effect of pre-treatments on physical properties, ascorbic acid and β-carotene content of frozen sweet corn kernels of the Hibrimas variety.

MATERIALS AND METHODS

Raw material

New variety of hybrid sweet corn, Hibrimas (*Zea mays* var *saccharata* Bailey) were obtained from FAMA Kelantan from a farm at Kampung Paloh, Tanah Merah, Kelantan.

Pre-treatments of frozen sweet corn kernel Hibrimas

Fresh sweet corns were dehusked, washed and subjected to different pre-treatment methods: Hot water blanching (blanching with 100ºC boiling water for 5 min), Steam blanching (blanching with 100ºC steam for 11 min), Citric acid blanching (blanching with 0.5% citric acid solution at 100ºC for 5 min), Sodium chloride blanching (blanching with 2.0% sodium chloride solution at 100ºC for 5 min), Sodium metabisulfite blanching (blanching with 1.0% sodium metabisulfite solution at 100ºC for 5 min). One sample that does not subject to any treatments was set as control. Inactivation of enzyme after blanching is determined via catalase enzyme test using 1% hydrogen peroxide solution.

Freezing process

The pre-treated Hibrimas sweet corns cobs were undergoes kernel cutting process prior to blast freezing for 10 min for the corn kernel to reach temperature of -18ºC.

Analysis of physical properties

Weight lost, texture (hardness), colour, pH and total soluble solid readings were taken for every storage time of week 0, 3, 6 and 9.

Determination of ascorbic acid content

25 mL juice of corn kernel juice and 12.5 mL 20% metaphosphoric acid was added into 50 mL volumetric flask and top up with distilled water. 10 mL of sample solution was then pipetted into a conical flask and 2.5 mL of acetone was added into it. The sample solution was titrated with 2, 6 dichlorophenoliodophenol (DCPIP) indicators until a light pink colour was formed (AOAC, 1995).

Determination of β-carotene content

1 g sample in 5 mL of chilled acetone was centrifuged at 1370 x g for 10 min. The absorbance of the extract was determined at 449 nm wavelength in a UV-Vis spectrophotometer. Other extracts of diethyl ether, acetonitrile and methanol also prepared in similar manner as mentioned for acetone extraction (Biswas *et al.*, 2011).

Statistical analysis

Experimental data were analysed using one way analysis of variance (One-way ANOVA with Multiple Comparisons) and significant differences among means ($p < 0.05$) were determined by Fisher's LSD using MINITAB software (14.12.0 version). For data that not fulfilling equal variance test such as Bartlett's test or Levene test, a non-parametric test (Kruskal-Wallis test) was used to test the significant different among median of samples. Then, post hoc test (Mann-Whitney test) was used to analyses the significant different among all possible pair of samples.

RESULTS AND DISCUSSION

Optimum blanching time and chemical concentration

Blanching vegetables to inactivate endogenous enzyme like peroxidase is a critical step prior to freezing (Barrett, 2000). Yet, blanching time is crucial in controlling the endogenous enzyme inactivation without further cause the loss of colour, texture and flavour of corn. Thus, blanching time was studied for physical pre-treatments like hot water blanching and steaming pre-treatments using catalase test. Corns blanched for 2, 4, 5 and 6 min with hot water and corns steam blanched for 6, 8, 10, 11 and 12 min undergoes catalase test using 1% hydrogen peroxide (H_2O_2) respectively. It is interesting to note that, the shortest possible times in inactivating endogenous enzymes were 5 min for hot water blanching and steaming for 11 min. Thus, both blanching times were set as optimum times to pre-treat corn on cobs (Table 1).

Chemical blanching by using food grade citric acid, sodium chloride (NaCl) and sodium metabisulfite ($Na_2S_2O_5$) are mainly used to preserve foods' colour by retarding enzymatic browning (Kmiecik *et al*., 2008; Queentasari *et al*., 2012). Thus, in this study, optimum percentage concentrations of chemicals used were chosen based on hue value taken on the blanched corn cobs with different chemical pre-treatments. Hue angle value, calculated as $\tan^{-1}$ (b*/a*), can be considered as an index of the enzymatic browning (Nicoli *et al*., 1994). According Severini *et al.* (2003) positive a* values, testified a change from green to red colour and therefore a progressive browning which is undesirable. In contrast, constantly negative a* values were indices of enzymatic stabilization. Thus, optimum percentage concentrations of chemicals were selected based on hue angle nearest to control (93.64º), with a negative a* values. Citric acid 0.5%, sodium chloride 2.0% and sodium metabisulfite 1.0% were chosen due to their optimum hue angles with negative a* values (Table 2).

Table 1. Catalase test for hot water blanching and steaming pre-treatment

Hot water blanching time (min)	Catalase test for hot water blanching	Steaming time (min)	Catalase test for steaming pre-treatment
2	+++	6	++
4	++	8	+
5	–	10	+
6	–	11	–
		12	–

Note: +++ Vigorous bubbles, ++ Moderate bubbles, + Few bubbles, – No bubbles.

Table 2. Colour L* a* b* and hue values for corn cobs treated with different pre-treatment methods

Pre-treatments	Colour values			
	L*	a*	b*	Hue (º)
Control (Untreated)	69.64	-1.93	30.26	93.64
Water blanch (5min)	60.47	-2.95	30.73	95.48
Steam (11 min)	61.98	-2.27	34.92	93.71
Citric acid 0.1%	66.89	-4.23	29.04	98.29
Citric acid 0.3%	62.86	-6.22	33.44	100.54
Citric acid 0.5%	64.39	-4.35	37.76	96.56
Citric acid 0.7%	60.39	-5.92	32.17	100.42
Citric acid 0.9%	65.38	1.56	37.75	87.64
Sodium chloride 1%	66.68	-5.38	27.54	101.04
Sodium chloride 2%	64.87	-4.62	32.92	97.99
Sodium chloride 3%	56.72	-4.45	21.75	101.57
Sodium chloride 4%	63.80	0.56	35.08	89.09
Sodium metabisulfite 0.5%	61.33	-5.24	26.44	101.20
Sodium metabisulfite 1.0%	58.09	-4.17	24.51	99.65
Sodium metabisulfite 1.5%	68.80	0.91	35.11	88.52
Sodium metabisulfite 2.0%	61.35	2.28	35.80	86.36

Colour of product is measured in L*a*b*. The L*a*b*, or CIELab, colour space is an international standard for colour measurements, adopted by the Commission Internationale d'Eclairage (CIE) (1976). L* is the luminance or lightness component, and parameters a* (from green to red) and b* (from blue to yellow) are the two chromatic components.

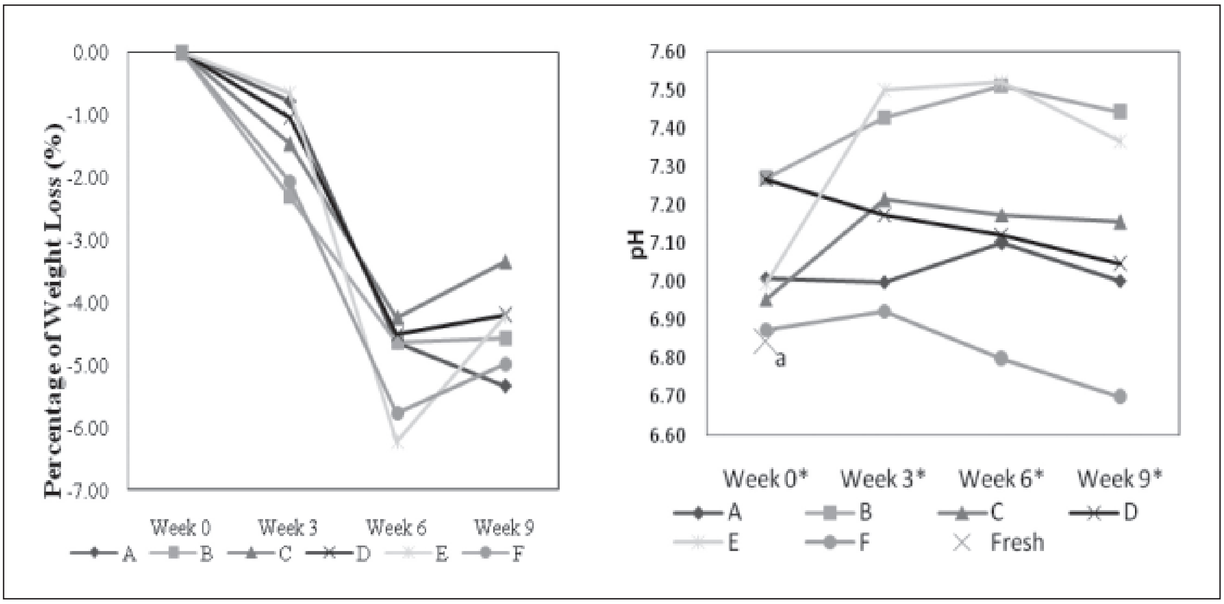

Fig. 1. Effect of pre-treatments on percentage weight loss and pH of corn kernels during storage.
Note: Means are reported from 2 duplicates. There are no significant different among the means within the same column (p>0.05). Key: A – Untreated (Control); B – Water blanching (5 min); C – Steaming (11 min); D – 0.5% Citric Acid; E – 2.0% Sodium Chloride; F – 1.0% Sodium Metabisulfite * Indicates data that analysed using non-parametric test.

Physicochemical properties of frozen sweet corn kernels

There were no significant different (p>0.05) on percentage weight loss for different pre-treatments. This finding was in contradiction with Tembo *et al.* (2008) which showed lower weight loss in blanched fruits compared to the unblanched ones. The chart of percentage weight loss showed downward trend across the storage time for all the samples. This means there was increasing weight loss as the frozen storage increases. During frozen storage, food samples lose water due to difference between the water vapour pressure on food surface with the surrounding atmosphere which formed the driving force of dehydration (Campanone *et al*., 2005; Ngcobo *et al.,* 2013). Figure 1 shows the percentage weight loss and pH of frozen corn kernels with different pre-treatments and stored for particular weeks.

Result also shows that there were higher pH values in water blanched, steamed, citric acid blanched and salt water blanched samples compared to control, except for sodium metabisulfite blanched sample. The elevated pH in water blanched sample can be explained by a higher extraction of soluble compounds during blanching and the loss of organic acids in the blanching water (Martinez *et al*., 2012). On the other hand, the increase in pH of chemical blanching method like salt water blanching samples were expected. This is supported by Mpotokwane *et al.* (2013) who relate this to the presence of the acidic chloride anion in sodium chloride salt water blanched pre-treated samples. From the result, sodium metabisulfite blanched sample showed lowest pH or most acidic value and this result is comparable to the study of Coskun *et al.* (2013) where sulphuring pre-treatment can affect and lower the pH value of sample. The lower pH in sodium metabisulfite pre-treatment was probably due to the action of the sodium metabisulphite in enhancing the release of free hydrogen ions from the sample and making it more acidic (Afoakwa *et al.,* 2013). In addition, sodium metabisulfite blanched sample showed further drop in pH as the storage time increased. Overall, steam pre-treatment had the least pH drop along storage period and this means steaming 11 min was effective in controlling grain deterioration by stabilise the pH of product.

Pre-treatments also showed significant effect (p<0.05) on texture of samples. Pre-treated samples were softer than the control. Theoretically, control (unblanched) sample should be the softest in texture due to the presence of polygalacturonase enzyme which was still active and catalysing the softening of sample (Barrett *et al*., 2000). However, in this case where blanched samples appeared to be softer than the control during storage was probably due to the blanching which cause cell damage and hence resulting in the loss of turgor pressure. Without turgor pressure, cells could not retain their shape (Waldron *et al*., 2003). Next, sample that blanched with 1.0% sodium metabisulfite showed to retain hardness of corn kernels better compared to other pre-treatments. A study of Sun (2011) showed that soaking in low pH solution is effective in lowering the internal pH of carrot, thereby retarding β-elimination and consequently texture degradation.

Table 3 shows L* value (lightness), a* value (greeness) and b* value (yellowness) of pre-treated corn kernels. Control had the highest L* value compared to pre-treated samples. This is similar to the finding of Barrett *et al*. (2000), where lightness value for unblanched sample was found to be the highest. The lower lightness in blanched samples can be explained by processing with high temperature and time contributes to the shrinkage of the tissue structure and increase sample opacity (Goncalves *et al*., 2010). Results also exhibited that among the pre-treatments, acid blanching like citric acid and sodium metabisulfite yield brighter samples as mentioned by Queentasari *et al.* (2012) where L* value increases with increase in acid concentration. Besides, there was no significant difference in lightness between water blanching and steaming pre-treatments. The colours of corn kernels were faded during storage. Cecelia (2008) mentioned increasing storage time often results in loss of brightness, greenness, and increasing in L* value of products.

Pre-treatments had significant effect on the greenness, a* value of frozen corn kernels. Water blanched and citric acid blanched samples had the highest greenness whereas sample blanched with sodium metabisulfite had the lowest greenness value. This result indicated that water blanched and citric acid pre-treatments were better in retaining chlorophyll pigment in sweet corn and gave desirable high greenness in sample. Higher a* value found in sample blanched with sodium metabisulfite is similar to finding of Sulaeman *et al*. (2001) in carrot chips. In this case, higher a* value was not desired since it indicated the degradation of chlorophyll a and b in blanching (Sun, 2011). In addition, higher a* value or more orange-red colour also means the corn kernels subjected to caramelization during the blanching process (Barrett *et al*., 2000). On the other hand, pre-treated samples give significant differences ($p<0.05$) in b* value (yellowness) of samples. All pre-treated samples had increased b* value or more yellow than the control and fresh sample. This is because pre-treatment causes the breaking down of crystalline carotenoid complexes and increased availability of carotenoid pigment (Hiranvarachat *et al*., 2011). Both acid blanching using citric acid and sodium metabisulfite obtained highest yellowness b* value compare to others. This indicated acid can act as effective chelator in preventing browning reaction and gave desirable yellowness (Hiranvarachat *et al*., 2011).

Total soluble solid (TSS) is an index of soluble solids concentration in food and can be measured in ºBrix (Javanmardi and Kubota, 2006). Figure 2 shows the total soluble solids of samples with different pre-treatments during 9 weeks of storage. Steam pre-treatment showed great dropped in ºBrix value, whereas control, water blanching, citric acid and sodium chloride pre-treated samples showed

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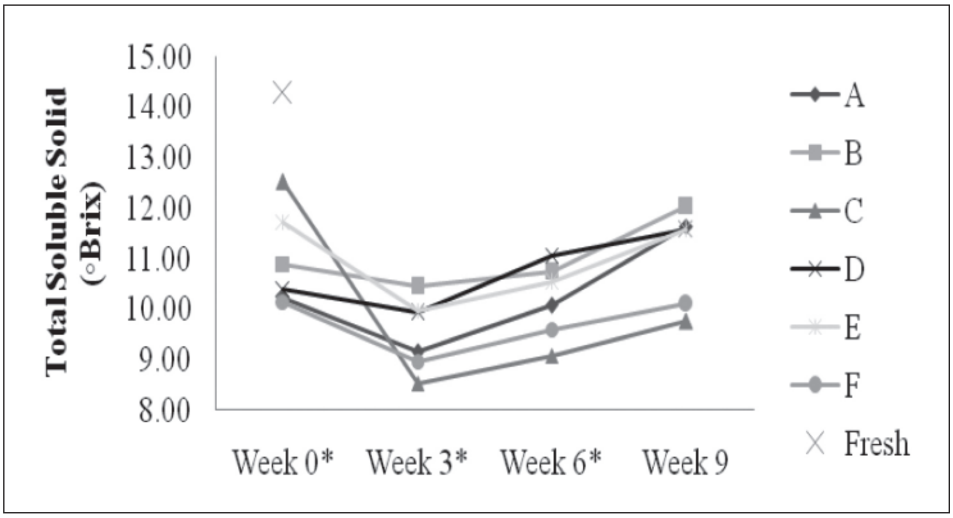

Fig. 2. Effect of pre-treatments on total soluble solids of sample during storage.
Note: Means are reported from 2 duplicates. Means within the same column showing the same superscript letter are not significantly different ($p>0.05$). Key: A – Untreated (Control); B – Water blanching (5 min); C – Steaming (11 min); D – 0.5% Citric Acid; E – 2.0% Sodium Chloride; F – 1.0% Sodium Metabisulfite * Indicates data that analysed using non-parametric test.

high ºBrix values. From this point of view, water blanching, citric acid and sodium chloride pre-treatments had better total soluble solids retention ability. The loss in soluble solids in steam pre-treatment might be due to the longer heating process of 11 min and similar finding is showed by Trongpanich *et al.* (2002), where through the finding shows that heat treated samples show higher loss in total soluble solids. Next, increasing trend in ºBrix was showed after week 3 of storage and this indicated the possibility of enzyme reactivation after blanching. Slight reactivation of enzyme pectin esterase after a 99ºC blanch was reported by McFeeters *et al.* (1985), and regeneration of heat stable enzyme peroxidase was observed within 2 months after blanching and freezing of green beans and turnips (Reed, 1966). Thus, the increase in the soluble sugars could be the result of reactivation of endogenous amylases in samples. Amylase is a carbohydrate splitting enzyme which hydrolysed starch to yield monomeric carbohydrates (Karim *et al*., 2008). Besides, hydrolysis of cell wall constituents could also contribute to the observed increase in ºBrix (Ezz *et al.,* 2004).

The result also showed all pre-treated samples were significantly higher in ascorbic acid content than the control (data not shown). This result was in agreement with the finding of Gao *et al.* (2012) where blanching showed to increase ascorbic acid content in sour cherry juice. Blanching can prevent ascorbic acid loss probably due to the inactivation of enzyme which dominates enzyme-induced oxidation that causes the loss of ascorbic acid (Martinez-Romero *et al.,* 2003). There was significant different ($p<0.05$) in ascorbic acid content of frozen corn kernels subjected to different pre-treatments. Chemical blanching using citric acid, sodium chloride and sodium metabisulfite showed to have higher ascorbic content than steam blanching, yet not significant different with water blanching. Chemical used in pre-treatment like potassium metabisulfite, magnesium oxide and sodium bicarbonate are proved to offer protection against oxidation of ascorbic acid and more advantageous than conventional water and steam blanching (Gupta *et al.,* 2008). Sodium meta-bisulfite had the highest ascorbic acid among the pre-treatments and similar result was showed by Inyang and Ike (1998) where blanching in sulphite solution led to the retention of more of the colour components and ascorbic acid during dehydration. High concentration of sodium metabisulfite decreased the pH and thus, facilitates the retention of ascorbic acid (Afoakwa *et al.*, 2013).

Figure 3 shows the β-carotene content of sample which had undergoes different pre-treatments and stored for several weeks. There was no significant different ($p>0.05$) in effect of pre-treatments on the β-carotene of frozen corn kernels. However, previous studies showed increased of β-carotene in frozen carrot (Dutta *et al*., 2005) and Tanzanian vegetables (Mosha, 1997) after blanching. Study of Lisiewska *et al.* (2004) also showed blanching, freezing, and storage of refrigerated products, irrespective of temperature, did not change the contents of components analysed in the first 3 months. Next, there was obvious degradation of β-carotene content after week 6. This was similar to finding of Coskun

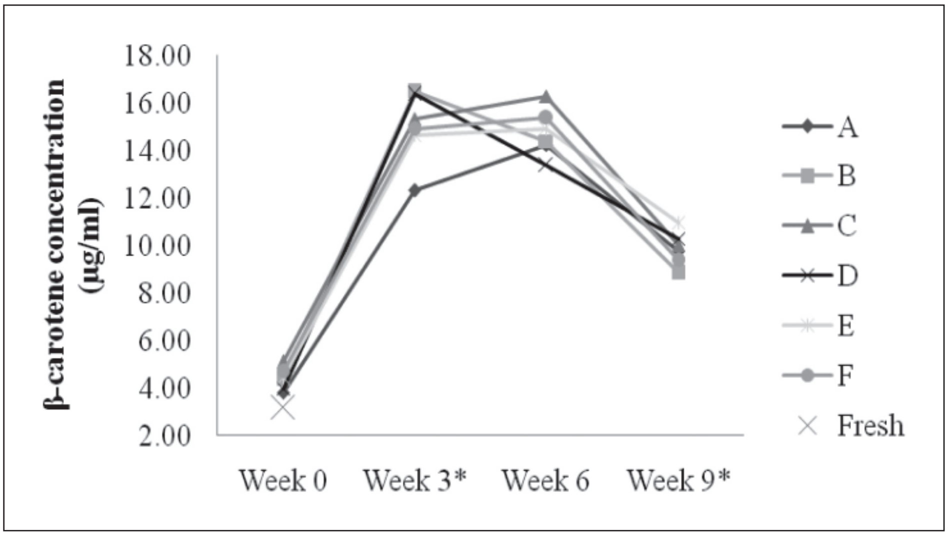

Fig. 3. Effect of pre-treatments on â-carotene content in frozen corn kernels during storage.
Note: Means are reported from 2 duplicates. Means within the same column showing the same superscript letter are not significantly different (p>0.05). Key: A – Untreated (Control); B – Water blanching (5 min); C – Steaming (11 min); D – 0.5% Citric Acid; E – 2.0% Sodium Chloride; F – 1.0% Sodium Metabisulfite
* Indicates data that analysed using non-parametric test.

et al. (2013) where storage time had more significant effect on β-carotene content. The degradation of β-carotene content probably due to non-oxidative changes such as cis-trans isomerization and epoxide formation (Coskun *et al.*, 2013; Dutta *et al.*, 2006) or β-carotene reacted with air present in head space during storage which caused the loss of carotene of samples (Kaur, 2013).

CONCLUSIONS

Pre-treatments had significant effects on physicochemical and sensory acceptance of frozen corn kernels variety Hibrimas. For physical properties, sodium metabisulfite pre-treatment produced sample with highest hardness. High lightness (L) was observed in corn kernels blanched with acid like citric acid and sodium metabisulfite. High greenness (a) in water blanching and citric acid blanching indicating both pre-treatments were good in retaining chlorophyll pigment. In terms of yellowness, citric acid and sodium metabisulfite pre-treatments gave high yellowness in sweet corn kernels. Water blanching, citric acid and sodium chloride blanching showed to have high total soluble solids retention. Steam blanching was able to stabilise pH of frozen corn kernels during storage and lower risk of grain deterioration. In terms of ascorbic acid, sodium metabisulfite pre-treatment had highest ascorbic acid retention ability. Thus, citric acid pre-treatment is suggested as the best pre-treatments to frozen Hibrimas corn kernels due to its high colour and total soluble solids content. Therefore, pre-treatments are able to increase efficiency of corn kernels by combining more than one pre-treatment during food production. This data could be one of the solutions in combating food insecurity as well as to maintain sustainability in food resources.

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