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Effect of Combined Infrared and Hot-Air Drying on the Chemical and Color Characteristics of Sweet Potato Slices

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ABSTRACT

Utilization combined infrared and hot-air drying strategies for sweet potato with and without pretreatment under different levels of air-drying temperature, infrared radiation and thickness and its impact on chemical and color attribute. Evaluation tests showed that total soluble sugar and total carbohydrate content increased with the increase of air-drying temperature and infrared radiation. While it decreased with the thickness of the slices increasing. The high values for all soluble sugar and carbohydrate were 0.802 and 0.452 mg/ml (in untreated) and 0.833 and 0.512 mg/ml (in treated) under the condition of the highest temperature and infrared radiation level and less thickness. β-carotene was decreased with the increase of temperature, slices thickness and infrared radiation intensity, The high value of β-carotene were 0.49 and 0.64 mg/100 g, respectively (for untreated and treated slices) at the lowest temperature, infrared radiation level and thickness. For color, the maximum lightness (L*), redness (a*) and hue angle (H°) were 74.62,15.7 and 88.53 for treated sweet potato slices while the maximum yellowness (b*), chrome (C) and Browning Index (BI) were 55.46, 55.53 and 208.29 for untreated sweet potato slices, respectively.

Keywords: sweet potato, drying, color, infrared, and β -carotene

INTRODUCTION

Sweet potato (Ipomea batatas L.) is a plant that belongs to the Convolvulaceae family. It is hearty vegetable yield food in numerous nations in Egypt. Typical sweet potato yield in 2015 was 10.43 ton/feddan but in 2020 expanded to 10.45 ton/feddan. Sweet potato creation expanded in Egypt from 408280 tons to 450985 tons during 2015-2020. Region reaped expanded additionally from 11933 to 13154 ha, separately (FAO, 2021). There is a higher grouping of supplements, for example, ß-carotene, vitamin A, L-ascorbic acid, and iron, minerals like calcium, phosphorus, iron, potassium, magnesium, and zinc in sweet potato than in rice and wheat flour. It is a decent wellspring of fiber which assumes a good part in lessening blood cholesterol levels, (Alloush, 2015).

Many examinations have shown that sweet potato has a lot of advantages such as calming (Kim *et al*., 2012), antimicrobial (Konczak-Islam *et al*., 2003), anticancer (Tang *et al*., 2015), hostile to stoutness (Wang *et al*., 2016), antioxidative (Zhu *et al*., 2010) & (Kim *et al*., 2012) and (Li *et al*., 2014), anticancer (Tang *et al*., 2015), antidiabetic (Konczak-Islam *et al*., 2003), hepatoprotective (Li *et al*., 2012), and antiaging properties (Wang *et al*., 2016).

To protect food from microbial tainting that decreases water movement by diminishing dampness content by a drying strategy (Nguyen *et al*., 2018). High temperatures usage can be downward healthy profit and harm starch particles; other than that, treatment with warming, that has a lot of carbohydrates, particularly sugar will be faced which can likewise cause broad harm can be happened by caramelization non-enzymatic for sugar (Syarfaini *et al*., 2017).

Sweet potato is very rich in energy and starch. By drying the sweet potato crisps the carbohydrate content of it upgrading from 62.17 to 74.97% by increasing temperature (Fetuga *et al*., 2014). Onwude *et al*., (2018) using new strategies in the drying of sweet potato convective hot-air, IR (infrared), and merged IR-CHAD (infrared- drying convective hot-air drying). The drying energy were influenced by the thickness of sweet potato cuts for every drying strategy because of 6 mm sweet potato had longer drying time. It was additionally seen that an expansion in the cut thickness came about to a high vary in the a* and b* color values particularly at a high temperature and force.

The redness/greenness (a*) of all dried samples were diminished altogether. The combination of infrared with hot air provides an efficient drying process, (Wanyo *et al*., 2011). The standard selection drying procedures depend on color (Wang *et al*., 2014) and (Gilandeh *et al*., 2020).

The mix procedures between the different infrared (IR) and hot air drying (HAD) led to changes (b*, L*, ∆E and a*) of dehydrated sweet potato by different mix techniques because gelatinization of starch which has been formed for to affect the visual features of sweet potato (Lee and Lee, 2017; de Oliveira *et al*., 2015; Ramesh Yadav *et al*., 2006). For keeping the antioxidant compounds, the experimental carried out pretreatments before drying. Olatunde *et al*., (2016) illustrated that sweet potatoes treated with 1 % lemon juice solution for10 min. after putting in 1 % sodium meta-bisulphite before solar drying.

Biochemical parameters of sweet potato flour, the high value of total sugar (45.56 %) and carotenoid content (2.03 mg/100g) (jethva, *et al*., 2016). Quality attributes of foods and acceptance of food products by consumers depend on the important critical element of its color. It underwent a serious deterioration during drying, largely caused by enzymatic and non-enzymatic browning, (Denga *et al*., 2017). Carotenoids play an essential role as an antioxidant for protecting the tissues and cells from peroxides and in a collection of lipid-soluble natural

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dyes that the indicator of vitamin A (He *et al*., 2017). Artificial and traditional methods of drying affect the quality parameters of the dried product. The main aims of the research were to detect the quality attributes of treated and untreated dried sweet potato slices by color and total soluble sugar, total carbohydrate content and beta carotene under using different levels of infrared radiation, drying air temperature and slices thickness.

MATERIALS AND METHODS

To accomplish the target of the current work, an exploratory scale was created and introduced at the Agricultural Engineering Department, Faculty of Agric. Tanta University. The dryer was utilized for directing the exploratory work for drying sweet potato during December 2020. Sweet potato was chosen for test work. Sweet potato arrangement included manual managing and stripping followed by cutting of the sweet potato with a homegrown slicer to different thickening.

After that, sweet potato slices were pre-treated, there were untreated slices (without any pretreatment) (Untreated) and treated by usage of 0.5: 1 % w/v (5 gm SMS in 1-liter water) sodium meta bisulphite and citric acid up to 30 min (Treated) then drying it with infrared radiation heating to prevent reasons browning before dried it, the concentration of sodium met bisulphite in the solution was reduced from 1 to 0.5% because of the threat of sensitivity, (Russell and Gould, 2003).

Variables under study were: (1) radiation intensity (0.861, 0.973, 1.093 and 1.161 kW. m^{-2}). (2) hot air temperature (45, 55 and 65 ºC), (3) slices thickening (1,3 and 5 mm) at constant air velocity (1.2 m. s^{-1}).

Quality Evaluation of the dried Sweet Potatoes

Determination of color indices:

In the first place, the color analyzer was aligned utilizing a standard adjustment plate with a white surface for R (red), G (green) and B (blue). The image processing is the conversion of RGB color units to L* a* b* (segment labelling) values necessary for graphics and analysis respectively. To convert the RGB color space of the image to CIELab color space is necessary to do it in two phases. The first phase converts from RGB to XYZ (Poynton, 1996), and the second of XYZ color space CIE Lab.

As a first step, it must normalize RGB to rgb values (values between 0 and 1). Subsequently were calculated the values of L*, a* and b* in the CIE Lab color space, such as the lightness (L*), redness (a*) and yellowness (b*). The average values of color parameters and standard deviations were calculated (L*, a*, b*, C and H). Metric color chrome (c) and hue angle (H°) values were calculated using the measured L*a*b* values. Wrolstad and Smith (2010) showed the changes in each color parameter were calculated as follows:

$$\textbf{Hue angle}(H^{\circ}) = \tan^{-1}\frac{b^*}{a^*} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \textbf{(1)}$$

$$C = \sqrt{a^{*2} + b^{*2}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \textbf{(2)}$$

Browning index (*BI*) is one of the finesse selectors in dried sweet potatoes apart from color and aroma. The browning index was calculated using L*, a*, b*. BI was calculated after drying using Equation (3) with *x* expressed as Equation (4) according to Dadali *et al*., (2007):

$$BI = \frac{X - 0.31}{0.17} * 100\% \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \textit{(3)}$$

$$X = \frac{a^* + 1.75\,L^*}{5.645\,L^* + a^* - 3.012\,b^*} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \textbf{(4)}$$

where L*, a*, and b* are values for the dried sample.

Determination of total soluble sugar

Total soluble sugar (TSS) is used for testing of sugar content in new and desiccated examples. The not set in designer when drying, Sulfuric corrosive, reagent evaluation 95.5%, adjusting to ACS particulars, literal gravitation 1.84 Hydroxybenzene 80% by coefficient, ripe by adding 20 grams of glass-refined water to 80 grams of redistilled reagent ablaut oxybenzene. This mixture shapes a water-white agent that is readily pipetted. The cylinders are permitted to stance 10 transactions, then, at that mark, they are shaken and set for 10 to 20 transactions in an element of rain at 25° to 30° C before readings are expropriated. The absorbance of the stylemark xanthous - orangeness feeling is estimated at 490 mµ for hexoses and 480 mµ for pentose and uronic acids. The shading is steady for quite a long time and readings might be made later if vital. How much sugar may not entirely set in stone by refencing a standard bend recently developed for the specific sugar in evaluation, (de Oliveira *et al*., 2015)

Chemical analysis of carbohydrate content

Reagents: 1-2.5N Hydrochloric corrosive: 24.46ml HCI (37%) is concluded to 100ml by dist. liquid.

2-Standard serials of glucose from working criterional ornamentation (0.1 mg/ml).

3-5% Dissolvent. 4-96% sulphuric destructive reagent ablaut.

Joining of infinite polysaccharide (mg/ml) is acquired from prescriptive movement. Proportionality of all out-carb present in dry comfort up in the air by succeeding strategy.

Absorbance relates to 0.2 ml of judge sample=X mg of glucose where X is the centralization of check, 0.2 is the arrogated loudness of essay. 100 ml of the check arrangement hold (X/0.2) * 100 % of all out-starch existed (Dulles *et al*.,1956).

Assurance of β-carotene

Two grams (2 g) from the substance were set by a mortar and then squashed with a pounder. A combination of hexane: propanone in the magnitude of 1:1 was side into the mortar. Around 5ml of solvent was superimposed gradually at passable spans. The solvents were gathered independently, and the interaction was rehashed with the representation for twofold extraction. The diverter involve carotenoids were sifted finished a channelize medium and afterward touched into an isolating piping. 50ml of superfine nutrient was another alongside 50 ml of 10% NaCl piece. The amalgamate was shaken irresistibly and preserved excursus for the layers to separate. The speed sheet contained carotenoids and it was concentrated independently after the ejection of the element and NaCl organization. The cerebrate was concentrated in pipes. Utilizing a calorimeter, the absorbance of the carotenoid was noted at 630 nm. How more current carotenoids in every 100g of food test detected (Rebecca *et al*.,2014).

RESULTS AND DISSCUSION

The influence of hot air and infrared on sweet potato color indices to investigate the effect of infrared radiation intensity and temperature on color change of sweet potatoes, four radiation intensity, three hot air temperature on different slice thickening which used. The highest value of lightness (L*) when using air temperature 45 ºC at infrared radiation intensity 1.093 kW. m^{-2} and 1mm thickness for treated slice of sweet potato was 74.62 while at untreated slice of sweet potato at these conditions (3mm thickness, air temperature 65 ºC and infrared radiation intensity 1.161 kW. m^{-2}) there was 73.45 the maximum value of lightness (L*) as illustrated in Fig. 1.

It agrees with Ertekin and Heybel, (2014) by using the temperature of 70ºC in drying, there are high effect on the dried samples the lightness valuable. (Alam *et al*., 2013)

Pretreatment and drying method affected 'L' values. The largest 'L' was (75.2) by dipping on 6% KMS after use water blanching pretreated at (55°C) dehydrated samples; the least value was (58.2) for untreated sample on (65°C) samples.

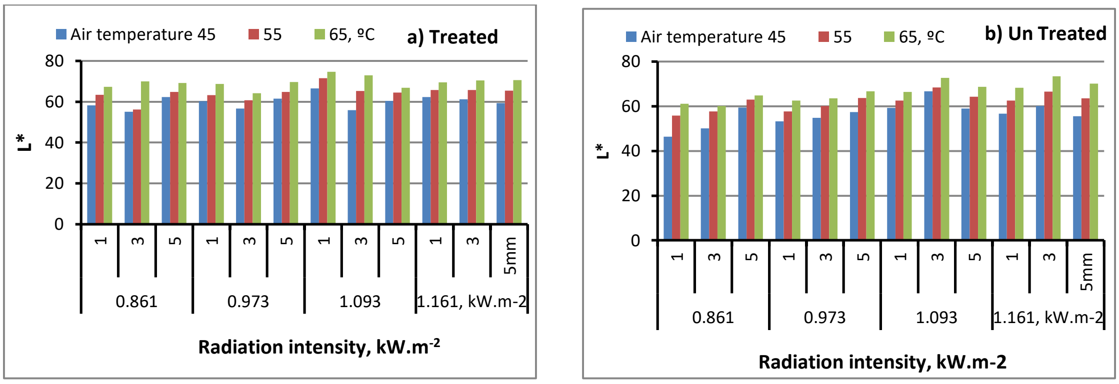

Fig. 1. Variation of lightness (L*) of potato slices with differing thickness and air temperature and infrared radiation intensity levels (a: treated, b: untreated)

The highest value of redness (a*) at 45 ºC air temperature and infrared radiation intensity of 1.161 of kW. m^{-2} and 5mm thickness for a treated slice of sweet potato while was 15.7 while at the untreated slice of sweet potato was 11.2 at these conditions (5mm thickness, air temperature 45 ºC and infrared radiation intensity 1.161 kW. m^{-2}) there was the maximum value of redness (a*) as illustrated in Fig. 2.

The same trend in other studies a* for the dried samples was influenced by the (temperature and time) and increased. The top a* values were at 45 ºC (5.93 ± 1.51) and 50 ºC (5.61 ±0.31). These color variations of redness (a* value) may be linked with browning reactions due to consuming drying times at minimum temperatures (Senadeera *et al*., 2020).

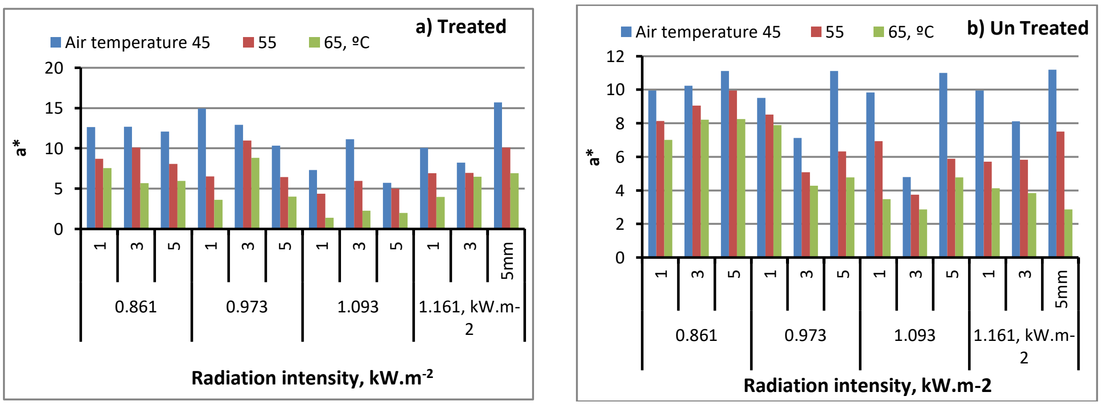

Fig. 2. Variation of redness (a*) of potato slices with different thickness dried and air temperature and infrared radiation intensity levels (a: treated, b: untreated).

The highest value of yellowness (b*) at using air temperature 45 ºC at infrared radiation intensity of 1.093 kW. m^{-2} and 1mm thickness for a treated slice of sweet potato was 54.39. While, at untreated slice of sweet potato was 55.46 at (5mm thickness, air temperature 65 ºC and infrared radiation intensity 1.161 kW. m^{-2}) there was maximum value of yellowness (b*) as illustrated in Fig. 3.

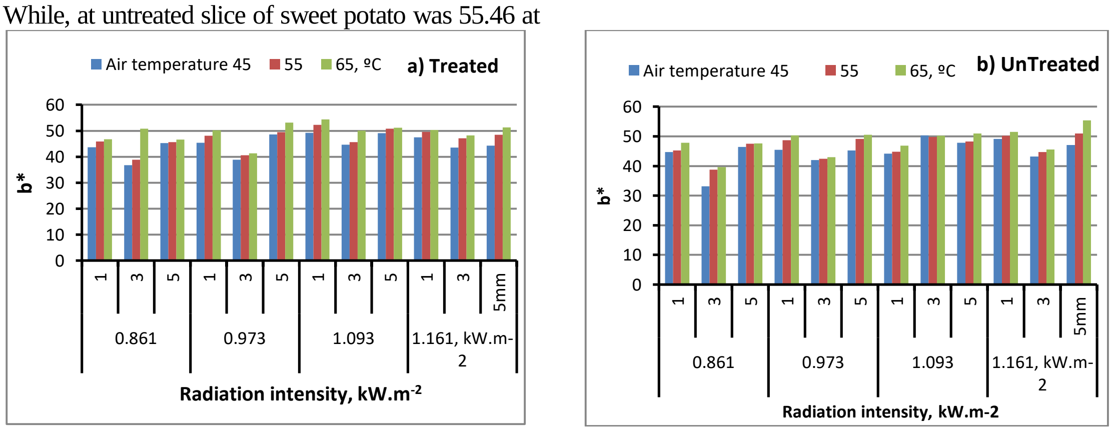

Fig. 3. Variation of yellowness (b*) of potato slices with different thickness dried at air temperature and various infrared radiation intensity levels (a: treated, b: untreated).

The highest value of chrome (C) when using air temperature of 65 ºC at infrared radiation intensity of 1.093 kW. m^{-2} and 1.0 mm thickness for treated slice of sweet potato was 54.41 while at untreated slice of sweet potato at these conditions (5 mm thickness, air temperature 65 ºC and infrared radiation intensity 1.161 kW. m^{-2}) there was 55.53 the maximum value of chrome (C) as illustrated in Fig. 4.

The highest value of hue angle (H°) at using air temperature 45 °C at infrared radiation intensity 1.093 kW. m^{-2} and 1mm thickness for treated slice of sweet potato was 88.53 while at untreated slice of sweet potato was 87.05 at these conditions (5mm thickness, air temperature 65 °C and infrared radiation intensity 1.161 kW. m^{-2}) there was maximum value of hue angle (H°) as illustrated in Fig. 5.

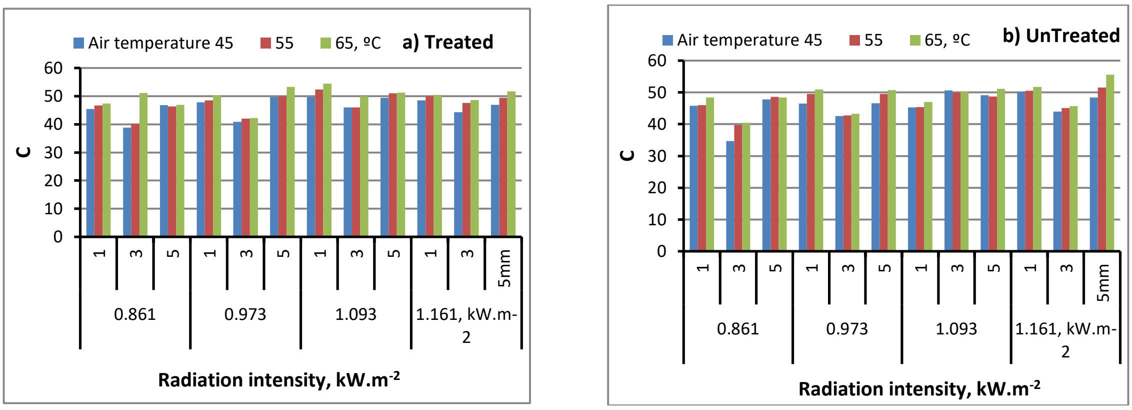

Fig. 4. Variation of chroma (C) of potato slices with different thickness dried at air temperature and infrared radiation intensity levels (a: treated, b: untreated).

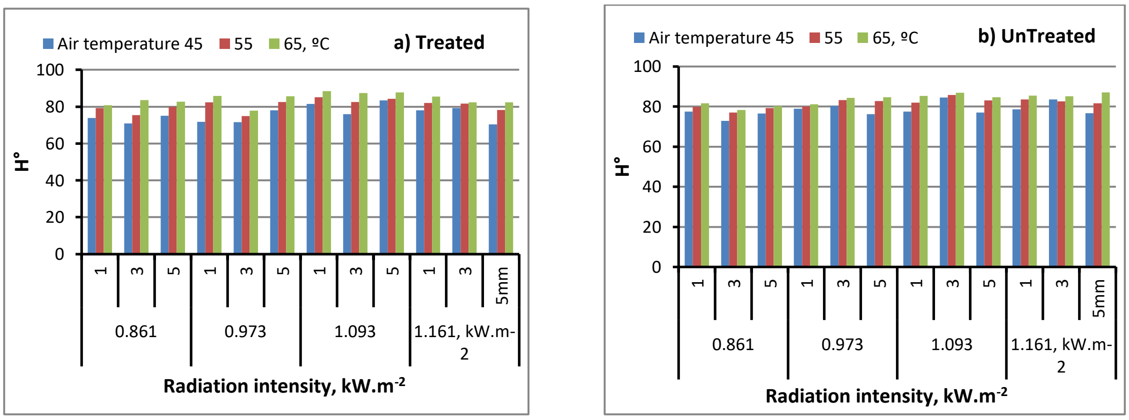

Fig. 5. Variation of hue angle (H°) of potato slices with different thickness dried at air temperature and infrared radiation intensity levels (a: treated, b: untreated).

The highest value of (Browning Index) BI at using air temperature of 45 °C at infrared radiation intensity of 1.093 kW. m^{-2} and 5 mm thickness for treated slice of sweet potato was 147.37 while at untreated slice of sweet potato at these conditions (1 mm thickness, air temperature 45 °C and infrared radiation intensity 0.861 kW. m^{-2}) there was 208.29 the maximum value of (Browning Index) BI while the value for fresh sample was 67.26 as illustrated in Fig. 6. Our results agreed with (Senadeera *et al.*, 2020) there is a difference on H in persimmon fruits that freshly and dried; the highest Hue angle values was on dried samples at 65 °C.

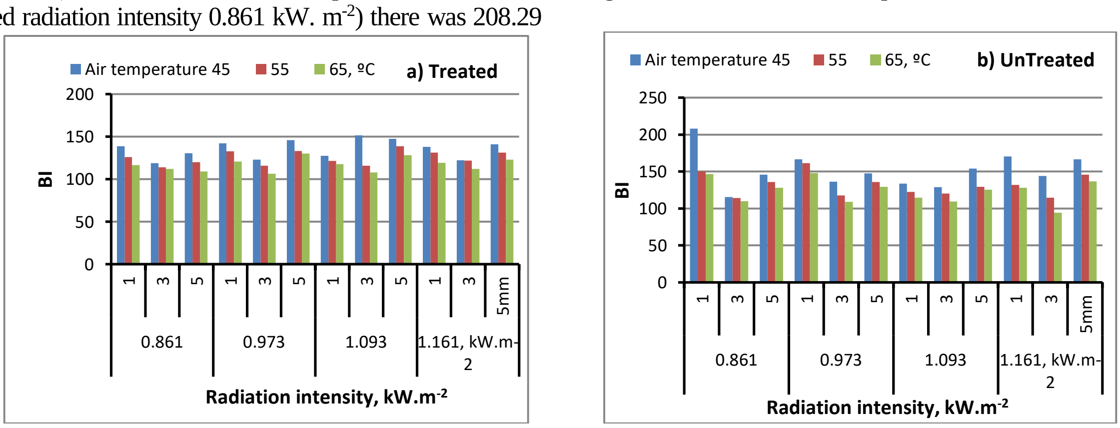

Fig. 6. Variation of browning index (BI) of potato slices dried at different levels of infrared radiation intensity and air temperature with different thickness (a: treated, b: untreated).

After the raising in browning index values there are increasing in darkening of dried product (Cuccurullo *et al.*, 2018). As the browning was occurred in dehydrated fruits more than the fresh (Zia and Alibas, 2021)

Dried sweet potatoes quality

In fresh sweet potato, the value of total soluble sugar content was 0.573 mg/ml. Changing the radiation intensity from 0.861 to 1.161 kW.m^{-2} for treated slices the total soluble sugar has grown from 0.642 to 0.723 mg/ml for 1mm thickness while increasing from 0.6 to 0.711 for 5 mm thickness, at the minimum air dryers of 45°c., Total soluble sugar has grown from 0.724 to 0.833 mg/ml for 1mm thickness, while, for 5 mm thickness increased from 0.639 to 0.823 mg/ml at the maximum drying air temperature of 65°c as shown in Fig. 7(a). Total soluble sugar content increased from 0.613 to 0.671 mg/ml at 1mm thickness. While at 5 mm thickness, total soluble sugar has grown from 0.54 to 0.689 mg/ml at the minimum air temperature of 45°c while at the maximum air temperature of 65°c total soluble sugar has grown from 0.693 to 0.802 mg/ml at 1mm thickness. While, at 5 mm thickness, increased from 0.599 to0.788 mg/ml for untreated slices as shown in Fig. 7(b). Total soluble sugar has grown with increasing air-drying temperature and radiation intensity, but it was decreased with increasing slices thickness. The very discernment in other studies the interchange in sum resolvable sweeten agnatic to oven temperature for integral, sliced lemons and full fruit with pretreatment respectively, (Nasr *et al*., 2021).

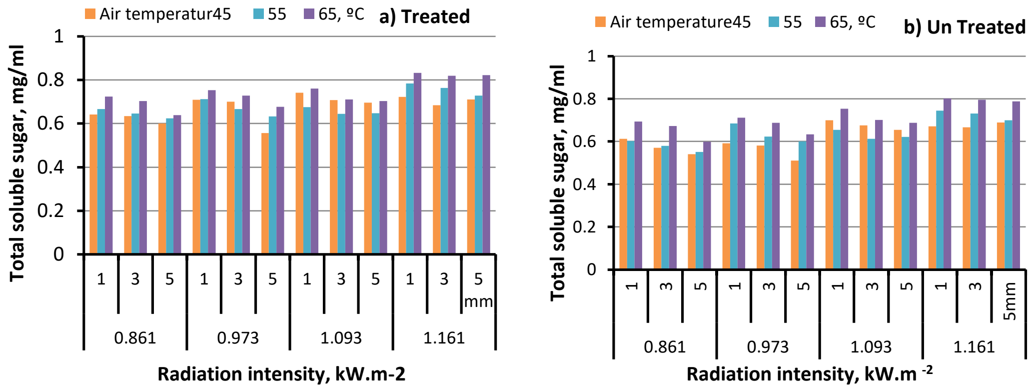

Fig. 7. The changes in total soluble sugar of the dried sweet potatoes at different levels of infrared radiation intensity, air temperature and slices thickness (a: treated, b: untreated).

Total Carbohydrate content was 0.106 mg/ml in the fresh sample while changing the radiation intensity from 0.861 to 1.161 kW.m^{-2} led to total Carbohydrate has grown from 0.228 to 0.409 mg/ml at 1mm thickness While, at 5 mm thickness, it increased from 0.231 to 0.417 mg/ml at the minimum air temperature of 45°c. while at the maximum 65°c air temperature the total Carbohydrate has grown from 0.306 to 0.512 mg/ml at 1mm thickness and from 0.289 to 0.474 mg/ml at 5 mm thickness, for treated slices as shown in Fig. 8(a). But for untreated slices, total Carbohydrate has grown from 0.199 to 0.381 mg/ml at 1mm thickness. While, at 5 mm thickness increased from 0.147 to 0.333 mg/ml at the minimum air temperature of 45°c. while at 65°c total Carbohydrate has grown from 0.271 to 0.452 mg/ml at 1mm thickness but increased from 0.239 to 0.404 mg/ml at 5 mm thickness as shown in Fig. 8(b). Total Carbohydrate has grown with increasing air-drying temperature and radiation intensity, but it was decreased with increasing slices thickness. The assonant trend in the range of carbohydrates in orange fleshed potato tubers ranged from 18±0.07 to 26.8±0.34% in the dehydrated sample. Dried potato has high value of carbohydrate than fresh because of increasing moisture content while its value in dehydrated samples was between 72.36±0.85 to 80.33±0.53% on dehydrated basis (Nicanuru *et al*., 2015).

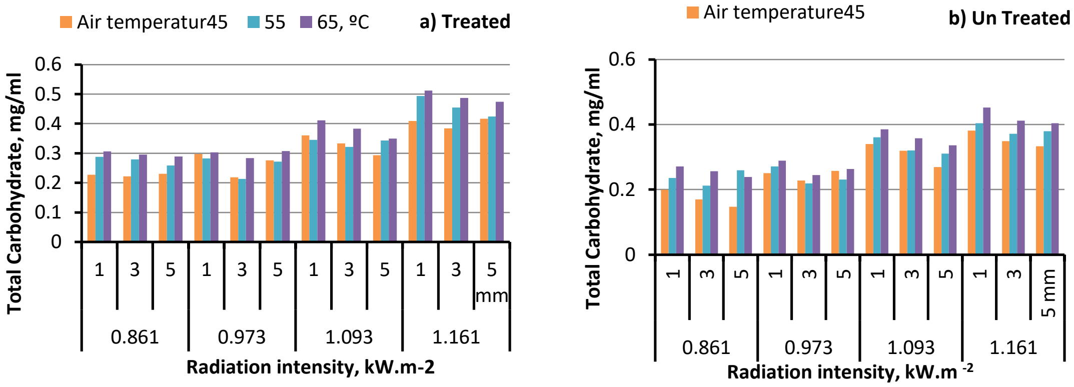

Fig. 8. The changes in total carbohydrate of the dried sweet potatoes at different levels of infrared radiation intensity, air temperature and slices thickness (a: treated, b: untreated).

Drying sweet potato slices at 45°C resulted in a low degradation rate of β-carotene. The degradation rate of β-carotene increased with air drying temperature and slice thickness. The β-carotene of sweet potato dried at 65°C and radiation intensity 0.861 kW.m^{-2}, decreased from 0.45 (mg/100g) at 1mm thickness to 0.19 (mg/100g) at 5.0 mm thickness at the same radiation intensity despite using radiation intensity 1.161 kW.m^{-2}, it dropped from 0.28 mg /100g at 1mm thickness to 0.2 mg /100 g at 5mm thickness for treated slices. But at 45°C, at 1mm thickness and radiation intensity while 0.861 kW.m^{-2} decreased from 0.64 (mg/100g) at 1mm thickness to 0.54 mg /100 g at 5mm thickness while at radiation intensity 1.161 kW.m^{-2}, it dropped from 0.48 to 0.26 mg /100 g for treated slices as shown in Fig. 9(a).

Changing the radiation intensity from 0.861 to 1.161 kW.m^{-2}, β-carotene decreased from 0.49 to 0.40 (mg/100g) at 1.0 mm thickness. While, at 5.0 mm thickness decreased from 0.4 to 0.23 (mg/100 g) at the minimum air temperature of 45°c. β-carotene content decreased from 0.39 to 0.20 (mg/100g) at 1.0 mm thickness.

While, at 5.0 mm thickness, it decreased from 0.16 to 0.13 (mg/100g) at the maximum air temperature of 65°c for untreated slices as shown in Fig. 9(b). β-carotene decreased with increasing air-drying temperature, radiation intensity and slice thickness.

The highest β-carotene content was 0.54 mg/100g for fresh sweet potatoes while less value was for untreated dried. There are the connatural with Jayaraman and Gupta, (1995) showed that reduction in β-carotene at with temperature drying could cause accumulated oxidization evaluation of its increasing of polyunsaturated chemical build. Veda *et al.* (2008) showed that for preventing the dropping of β-carotene during heat processing products it should use citric resolvent

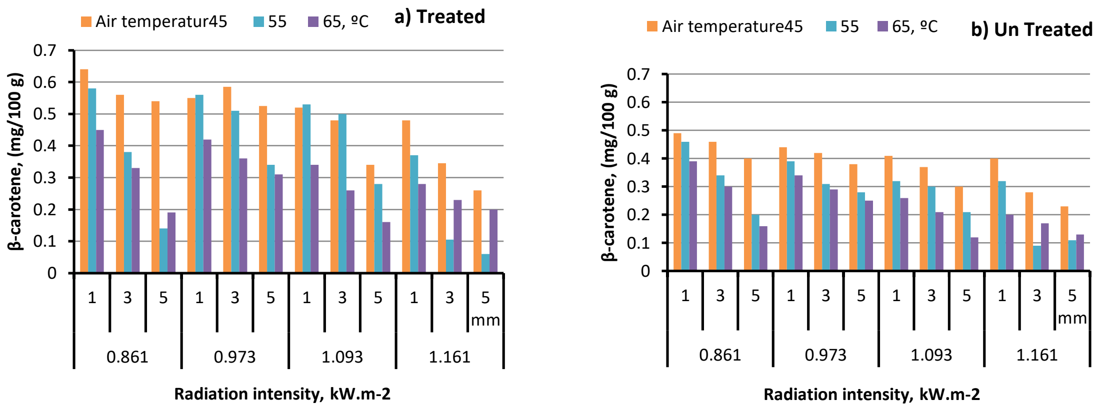

Fig. 9. The changes in β-carotene content of the dried sweet potatoes at different levels of infrared radiation intensity, air temperature and slices thickness (a: treated, b: untreated).

CONCLUSION

1-The intensity of infrared radiation and drying air temperature had a significant effect on color and quality of sweet potato slices .

2-Total soluble sugar content and Total carbohydrate content was increased with increase of air-drying temperature and infrared radiation, while it was decreased with increase of slices thickness.

3-The decay rate of β-carotene raised with temperature, slices thickness and infrared radiation intensity.

4- The color indices affected by treated and untreated sweet potato slices at different thickness and level of infrared radiation intensity.

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تأثير التجفيف المختلط بالأشعة تحت الحمراء والهواء الساخن على الخصائص الكيميائية واللونيه لشرائح البطاطا الحلوة

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اجريت التجربه بغرض دراسة اثراستخدام نظام التجفيف الهجين (الأشعة تحت الحمراء والهواء الساخن) على الخصائص الكيميائية واللونيه لشرائح البطاطا وذلك اربع مستويات من شدة أشعاع الأشعة تحت الحمراء وثلاث مستويات لدرجة الحرارة لسمك شرائح البطاطا ذات السمك المختلف سواء المعالجة والغير معالجة لمنع نشاط الإنزيمات المسؤلة عن التحول للون البنى. وقد شملت مؤشرات القياس: الخصائص الكيميائية (إجمالي السكر الذائب - محتوى الكربوهيدرات – بيتا كاروتين) والمؤشرات اللونيه – lightness (L*), redness (a*), yellowness (b*), chrome (C), hue angle (H°) , Browning index (BI) واظهرت النتائج أن قيمة إجمالي السكر الذائب - محتوى الكربوهيدرات – بيتا كاروتين في الشرائح المعالجة أعلى من الشرائح الغيرمعالجة وذلك عند أعلى درجة حرارة 65 درجة مئوية ومستوى إشعاع. 1.161 كيلو واط. م $^{-2}$ و 1 مم سمك ،. كانت أعلى قيمة بيتا كاروتين في الشرائح المعالجة عن الغير المعالجة (عند أدنى درجة حرارة 45 درجة مئوية ومستوى الأشعة تحت الحمراء عند 0.861 كيلو واط. م $^{-2}$ وسمك 1 مم. وبالنسبة للمؤشرات اللونية أظهرت النتائج أن (عند أدنى درجة حرارة تبلغ 45 درجة مئوية ومستوى الأشعة تحت الحمراء عند 0.861 كيلو واط. م $^{-2}$ وسمك 1 مم) وأظهرت المؤشرات اللونية أن الحد الأقصى (L*) و (a*) و (H°) كان 74.62 و15.7 و88.53 لشرائح البطاطا المعالجة ومن ناحية أخرى كان الحد الأقصى (b*) و (C) و (BI) كانت 55.46 و55.53 و 208.29 للشرائح غير المعالجة.

الكلمات المفتاحية : البطاطا الحلوة , التجفيف , الأشعة تحت الحمراء , اللون , البيتا كاوتين