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Changes in Some Chemical Composition and Colour properties of Fresh Carrot Slices and Carrot Pomace undergoing Drying

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ABSTRACT: This study compares the nutritional and colour properties of fresh and dried carrot slices and carrot pomace. Carrot tubers sliced into cubes and another processed by juice extraction into pomace were dried to equilibrium moisture content at a constant temperature of 60 °C in a hot air cabinet dryer. The nutritional values and colour properties of the samples were determined in laboratories before and after the drying process. It was observed that the fibre contents were found to be higher in the pomace than the fresh carrot slices and in the dried samples than the fresh samples. Also, there was significant difference in the carotenoid and vitamin C content between the fresh and dried samples. The pomace was found to dry faster than the sliced carrots, however, all the drying took place in the falling rate period. It was also discovered that lightness and yellowness was higher in the carrot pomace than the carrot slices, and the mean values for the colour parameters vary significantly between the fresh and dried samples.

Keywords: Chemical composition, Colour, Carrot, Pomace, Drying

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INTRODUCTION

Carrot (*Daucus carota* L.) is one of the most important root vegetable crops and is highly nutritious. Is a rich source of â-carotene and contains thiamine, riboflavin, vitamin B-complex and minerals (Walde *et al*., 1992). Carrot is an excellent source of calcium pectate; a pectin fiber that has cholesterol lowering properties, and reduces the risk of high blood pressure, stroke, heart disease and some types of cancer (Bakhru, 1993). It is greatly treasured as food mostly because it is the best source of carotene; a precursor of Vitamin A (Zeb and Mahmood, 2004). Moreover, carrot also contains abundant quantities of nutrients and minerals (Handelman, 2001; Nicolle *et al*., 2004). Carrot is an economically important horticultural crop that has gained popularity in recent decades due to increased awareness of its nutritional value. Among 39 fruits and vegetables carrots have been ranked 10th in nutritional value (Acharya *et al.*, 2008). The storage root of the carrot is the most commonly consumed portion of the plant. They are consumed uncooked in salads, steamed or boiled in vegetables and may also be prepared with other vegetables in the preparation of soups and stews (Anjum and Amjad, 2002). Apart from its food, value, carrot has therapeutic importance as it enhances resistance against blood and eye diseases (Pant and Manandhar, 2007). Carrots do not supply a significant amount of calories to the human diet, but do supply nutrients in the form of phytochemicals, such as carotenoids, anthocyanins, and other phenolic compounds. The greatest nutritional interest in carrots stems from their phytochemical content, but research has also focused on carrots as a source of fiber. Nutrient content of carrots can vary with cultivar (Nicolle *et al.,* 2004), season

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(Horvitz *et al.*, 2004), environmental conditions (Rosenfeld *et al.,* 1998), and maturity (Phan and Hsu, 1973).

Carrot is a good source of dietary fiber and of the trace mineral molybdenum, rarely found in many vegetables. Molybdenum aids in metabolism of fats and carbohydrates and is important for absorption of iron. It is also a good source of magnesium and manganese. Magnesium is needed for bone, protein, making new cells, activating B vitamins, relaxing nerves and muscles, clotting blood, and in energy production (Guerrera *et al.,* 2009). Insulin secretion and function also require magnesium (Bartlett and Eperjesi, 2008, Kim *et al.,* 2010). Manganese is helpful in carbohydrate metabolism, in coordination with enzymes in the body (Dias, 2012(a), 2012(b)). Manganese is used by the body as a co-factor for the antioxidant enzyme, superoxide dismutase. Potassium and magnesium in carrots help in functioning of muscles. Carrots are also a good source of energy because it contains a lot of sucrose.

Carrot pomace is the wet carrot shavings produced from carrot juice extraction. However, this pomace contains large amounts of valuable compounds such as carotenoids, dietary fiber (Nicolle *et al*., 2003), uronic acids and neutral sugars (Stoll *et al*., 2003). During commercial juice processing, 30–50 % of carrot remains as pomace (Bao and Chang, 1994) and up to 50 % of the carotene is lost with this pomace (Schieber *et al*., 2004). Nawirska and Kwasniewska (2005) have reported the composition of dietary fiber constituents of carrot pomace (on dry weight basis) as pectin (3.88 %), hemi-cellulose (12.3 %), cellulose (51.6 %) and lignin (32.1 %). Hence, by-product of carrot after juice extraction represent promising sources of compounds with bioactive properties that could be explored in the development of food ingredients and dietary supplements (Moure *et al*., 2001). Efforts have been made to utilize carrot pomace in foods such as bread, cake, dressings, pickle, fortified wheat bread (Filipini, 2001), preparation of high fiber biscuits (Kumari and Grewal, 2007) and production of functional drinks (Schweiggert, 2004). Carrot pomace contains 4–5 % protein, 8–9 % reducing sugar, 5–6 % minerals and 37–48 % total dietary fiber (on dry weight basis) and therefore, carrot products are known to be a good source of dietary fiber (Bao and Chang, 1994). Dried carrot pomace also contains 5.5 % of mineral components including iron, zinc, potassium and manganese which can enrich wheat bread mineral composition since wheat is a poor source of microelements (100 g supplies only 1.4 mg of iron) (Ambroziak, 1998). Dried pomace has â-carotene and ascorbic acid in the range of 9.87 to 11.57 mg and 13.53 to 22.95 mg per 100 g, respectively (Upadhyay *et al*., 2008). Dried carrot pomace can be used to develop exudates and flavors.

The nutritional food value of carrots changes depending on whether it is served cooked or raw. Studies have found that cooked carrots actually contain *more* of the antioxidants than raw carrots. This is because cooking carrots releases these antioxidants. Regardless of how carrot is eaten, cooked or raw, it provides the body with many of the essential vitamins and nutrients that are necessary for body growth.

The properties of dried vegetables are affected by chemical and physical changes. Chemical changes mainly affect sensory characteristics such as colour, taste and aroma where as physical changes affect handling properties such as swelling capacity and cooking time (Nijhuis *et al*., 1998). Maximum retention of â-carotene is of utmost importance for the preservation of the attractive appearance and dietary value of the product.

Therefore, the objective of this study is to investigate the differences in some chemical and colour properties of fresh and dried carrot slices and carrot pomace when dried.

MATERIALS AND METHODS

Sources of Materials

Fresh carrots (Daucus carota) tubers were procured from a local vegetable market in Akure, Nigeria. Carrot tubers were washed in a running tap water to remove impurities. The trashes were removed, trimmed with a plane stainless steel knife and washed thoroughly with portable water. The carrot tubers were divided into two (2) batches: Batch A was sliced into cubes of 8 and 10 mm sizes and batch B was carrot pomace - this is a product obtained after juice extraction from carrot using a juice extractor.

Drying Procedure

The two samples, that is, batch A and B were prepared for drying. 40 grams of each sample was spread in thin layer on paper carton wrapped with foil paper and placed on the tray of the hot air cabinet dryer. The samples were subjected to a constant drying temperature of 60 °C (Cui et al., 2004) and air velocity of 1.2 m/s, dried continuously to equilibrium moisture content (EMC).

The initial moisture content of each sample was determined by the oven method at 105 °C for 24 hours. The initial weight of each sample was determined and final weight was taken after oven drying using an electronic weighing balance. The moisture content was calculated as percentage moisture according to the method of Owoso and Ogunmoyela (2001).

$$M.C = \frac{M_1 - M_2}{M_1} \times 100 \qquad \text{eq. 1}$$

where:

M.C = Moisture content of the sample;

M_1 = Initial Weight of the Sample

M_2 = Final Weight of the Sample

Chemical Analysis

Chemical analysis was carried out to determine the vitamins A (carotenoids) and vitamin C, and fibre contents. All chemical analyses were carried out at the Professor Julius A. Okojie Central Research Laboratory, Federal University of Technology, Akure, Nigeria. Fresh samples of carrot slices and pomace were taken to the laboratory for the chemical analyses before and after drying. Three replicates were obtained per nutrient, per sample (treatment), mean values were then subjected to one-factor analysis of variance (ANOVA) using the General Linear Model (GLM) procedure of SPSS software version 20. Significantly different means were separated at the 95% significance level using the Duncan's Multiple Range Test (DMRT).

- *Vitamin A (Carotenoid)*

This was determined according to the method of AOAC, 2008 where 1.0 gram of each carrot sample was weighed into 20 ml acetone. The mixture was filtered after one hour. Thereafter, 10 ml of distilled water was added to the filtrate. The filtrate was then poured into a separating funnel. 5 ml of petroleum ether was added to the separating funnel, allowing it to flow into it by the side of the funnel. The mixture was left for a few minutes to separate, the lower layer was discarded. The concentration of the upper layer at 440 nm was measured, taking the acetone as the blank.

- *Vitamin C*

This was determined according to the method of AOAC, 2008 where 0.05 g of 2, 6 dichlorophenol – indophenol was dissolved in water. The mixture was made up to 100 ml (with distilled water) and filtered. 0.05 g of pure ascorbic acid was then dissolved in 60 ml of 20 % metaphosphoric acid and made up to 250 ml with distilled water. 10 ml of this solution was pipetted into a titration flask and titrated with dye solution until a faint pink colour persisted for 15 seconds. The strength of the dye solution was expressed as mg ascorbic acid equivalent to 1 ml of the dye solution.

➢ *Fiber content*

This was determined according to the method of AOAC, 2008 where Fritted crucibles were pre dried at 130±2 °C for 30 minutes. The pre dried crucibles were placed on a balance and tare. 1.0 g of carrot sample *(W_1)* was placed into a crucible containing 1.0 g celite 545 to simplify filtration. The fibertec hot extraction unit was switched on, 1.25% of H_2SO_4 was heated on hot plate. Using holder, the crucibles were inserted and lock into position in front of the radiator in the fibertec hot extraction unit ensuring that the safety latch engages. The reflector was placed in front of the crucibles and all values were put to closed position. Cold water tap (1 – 2 L/min) was opened for reflux system and 150 ml of preheated 1.25% of H_2SO_4 was added into each column as reagent 1. Then 2-4 drops of n-Octanol was added to prevent foaming. Reversed pressure was used to wash the sample three times with hot deionized water. 30 ml portion of water was used and suck as dry as possible between washings. 150 ml of preheated 1.25 % NaOH solution was added into each column as the 2nd reagent. The process was repeated from the start, before the crucibles were released with safety hook. The crucible holder was used to transfer the crucibles to the fibertec cold extraction unit.

Thereafter, the crucibles were well positioned in the fibertec cold extraction unit with the valves closed. 25 ml of acetone was added to each crucible and the solvent was extracted and filtered out by placing the valve in vacuum position, this process is repeated three (3) times. The crucibles were removed and transferred to the crucible stand and left at room temperature until the acetone has evaporated, to avoid risk of burning the fiber during the drying process. Crucibles were then dried for at least 2 hours at 130±2 °C, later cooled at room temperature in desiccators and weighed accurately to 0.1 mg *(W_2)*. The samples were ashed in the crucibles *(W_3)* at least 3 hours at 525±15 °C.

Calculation:

$$\%\ Crude\ Fiber = \frac{W_{2-}(W_3 + C)}{W_1} \quad \text{eq. 2}$$

where:

W_1 = Sample weight (g)

W_2 = Crucible + residue weight after drying (g)

W_3 = Crucible + residue weight after ashing (g)

C = Blank

Colour Analysis

Fresh samples of carrot and pomace were taken and their colour properties were determined using a Konica Minolta® CR-400 chromameter. The colour was analyzed in terms of the tristimulus colour values L, a, and b (lightness/ darkness, percentage red/green, and percentage yellow/blue hue, respectively: (Emekandoko, 2010; Perumal, 2007; HunterLab, 2012). Two major L-a-b colour systems exist for measuring colour: the Hunter scale and the CIE (Commission Internationale de l'Éclairage) scale. The CIE scale is a modification of the Hunter scale and was chosen due to its wide area of application in science today.

After drying, dried samples of carrot and pomace were taken and were also analyzed using the Konica Minolta® CR-400 chromameter. Calibration of the chromameter was done using a standard white tile (L^* = 86.4, a^* = 0.3158, b^* = 0.3236). Each sample was analyzed three times and the averages taken to obtain sample values for L, a and b. The sample values of L^*, a^* and b^* obtained were converted to ΔL^*, Δa^* and Δb^* by determining the difference between them and the standards, that is (Hunter and Harold, 1987):

$$\Delta L^* = L^*_{sample} - L^*_{standard} \quad \text{eq. 3}$$

$$\Delta a^* = a^*_{sample} - a^*_{standard} \quad \text{eq. 4}$$

$$\Delta b^* = b^*_{sample} - b^*_{standard} \quad \text{eq. 5}$$

A positive value of ΔL^* indicates that a sample is lighter than the standard, while a negative value indicates that it is darker than the standard. A positive value of Δa^* indicates that a sample

is redder than the standard while a negative value indicates that it is greener than the standard. A positive value of Δb^* indicates that a sample is yellower than the standard, while a negative value indicates that it is bluer than the standard. The standard used was a standard white tile with colour values $L = 86.4$, $a = 0.3158$ and $b = 0.3236$.

The standard chroma (C^*) value was then calculated as follows (Hunter and Harold, 1987):

$$C^*_{standard} = \sqrt{a^{*2}_{standard} - b^{*2}_{standard}} \quad \text{eq. 6}$$

Sample chroma values were calculated using:

$$C^*_{sample} = \sqrt{a^{*2}_{sample} - b^{*2}_{sample}} \quad \text{eq. 7}$$

Change in chroma (ΔC^*) was then determined as given by equation 8 (Hunter and Harold, 1987):

$$\Delta C^* = C^*_{sample} - C^*_{standard} \quad \text{eq. 8}$$

Total colour difference, ΔE^*, was then calculated using equation 9 (Hunter and Harold, 1987):

$$\Delta E^* = \sqrt{\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2}} \quad \text{eq. 9}$$

The hue (ΔH^*) for each sample was then determined from the following relationship in equation 10 (Hunter and Harold, 1987):

$$\Delta H^* = \sqrt{\Delta E^{*2} + \Delta L^{*2} + \Delta C^{*2}} \quad \text{eq. 10}$$

The hue (ΔH^*) values were subjected to one-way analysis of variance (ANOVA). IBM® SPSS version 20, 2011, was used for data analysis. Significantly different means were separated at the 95 % significance level using the Duncan's Multiple Range Test (DMRT).

RESULTS AND DISCUSSION

Chemical composition

The nutrients analysed are fibre, carotenoids (Vitamin A) and Vitamin C. The mean variations of these nutrients with fresh and dried samples of carrot and pomace are presented in Table 1.

The mean fibre values for dried carrot and pomace samples were significantly higher than the values obtained for fresh carrot and pomace samples. Also the fibre contents were found to be higher in the fresh and dried pomace than the fresh and dried carrot. This shows that the larger percentage of the fibre contents was left in the pomace even after carrot juice extraction. Carotenoids and Vitamin C contents in the fresh carrot and pomace samples were significantly higher than their dried samples; this implies that carotenoids and vitamin C decreases with drying. However, there was significant difference in the nutrients contents between the fresh and dried samples at 95 % significance level.

Drying rate

The carrot slices was dried from a moisture content of 86%wb to 6% in 9hrs while the pomace took 6 hours to reach equilibrium moisture content of 6% in 6 hours as shown in Figure 1. This indicates that the pomace dried faster than the carrot slices.

It was also discovered that the two products, that is the pomace and the carrot slices showed falling rate drying as shown in Figure 2. There was no constant rate drying as all the drying took place in the second phase of the drying regime where the internal water and bound water are released for drying by capillary action. This

Table 1: Mean variation of nutrients with fresh and dried samples

Nutrients	Fresh carrot	Dried carrot	Fresh pomace	Dried pomace
Fibre (mg/100g)	0.85 ± 0.27^{d}	28.68 ± 0.01^{b}	2.22 ± 0.02^{c}	56.02 ± 0.07^{a}
Carotenoids (mg/100g)	2.26 ± 0.06^{b}	1.25 ± 0.03^{d}	3.64 ± 0.04^{a}	1.72 ± 0.02^{c}
Vitamin C (mg/100g)	3.70 ± 0.05^{a}	1.02 ± 0.03^{c}	3.60 ± 0.01^{b}	0.79 ± 0.02^{d}

Means with different subscripts are significantly different ($P<0.05$)

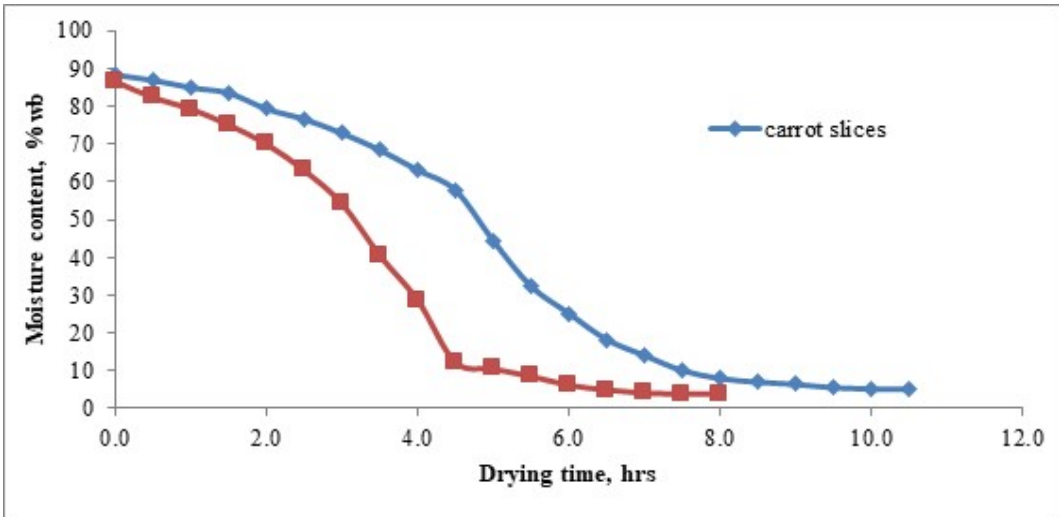

Figure 1: Drying curves for the carrot slices and carrot pomace

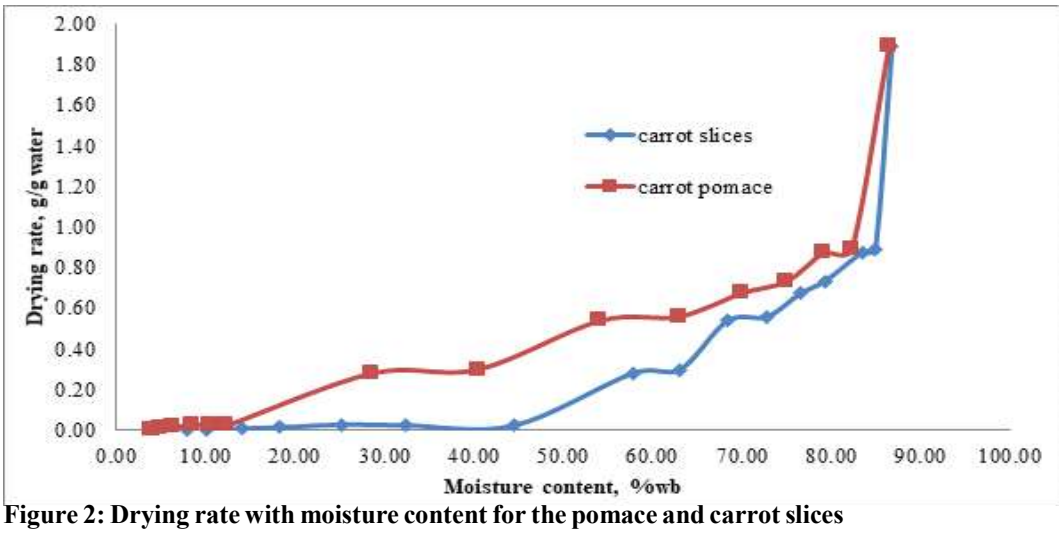

Figure 2: Drying rate with moisture content for the pomace and carrot slices

is the mostly the case with agricultural materials Nguyen and Price, (2007).

Colour Analysis

The colour indicators: Lightness/darkness (L*), redness/greenness (a*) and yellowness/ blueness (b*) were analysed in triplicate for the fresh and dried samples of carrot slices and pomace and their mean differences are presented in Table 2.

L* values were significantly higher for fresh samples than the dried samples. There was significant difference between the lightness of the fresh pomace and fresh carrot slices, as the lightness in the fresh pomace is higher than the fresh carrot. This may be as a result of the juice extracted from the carrot pomace. Also the a* (redness) value of the fresh carrot was higher than the fresh pomace, while the b* (yellowness) value of the fresh pomace was higher than the fresh carrot. However, there was significant difference between the fresh and dried samples for all the colour indicators.

Table 2: Differences in colour indicator measurements with fresh and dried samples

Colour indicator	Fresh carrot	Dried carrot	Fresh pomace	Dried pomace
L*	46.90±0.34^{bc}	45.06±1.02^{c}	52.04±0.93^{a}	48.52±0.76^{b}
a*	27.94±0.80^{a}	17.61±0.54^{c}	24.94±0.36^{b}	16.56±0.39^{c}
b*	24.16±0.73^{b}	18.76±0.54^{c}	28.04±0.37^{a}	22.34±0.66^{b}

Means with different subscripts are significantly different (P<0.05)

Table 3: Differences in calculated colour parameters with fresh and dried samples

Colour parameter	Fresh carrot	Dried carrot	Fresh pomace	Dried pomace
Chroma change *(ΔC)*	36.48±1.08^{a}	25.28±0.76^{b}	37.07±0.52^{a}	27.37±0.74^{b}
Colour difference *(ΔE)*	53.79±0.48^{a}	48.48±0.49^{c}	50.56±0.50^{b}	46.76±0.30^{d}
Hue *(ΔH)*	0.35±0.00^{b}	0.06±0.00^{d}	0.19±0.01^{c}	0.48±0.03^{a}

Means with different subscripts are significantly different (P<0.05)

The calculated values of chroma change (ΔC*), colour change (ΔE*) and the Hue (ΔH*) for the dried carrot and pomace samples were also analysed in triplicate and presented in Table 3. The mean chroma values for the fresh samples were significantly higher than the values obtained for the dried samples. There was no significantly difference between the chroma of the fresh carrot and fresh pomace, and between the dried carrot and dried pomace. The colour change between the fresh and dried samples was significantly different. Also the mean hue values for the fresh and dried samples vary significantly.

CONCLUSION

The nutritional and colour properties of fresh and dried carrot slices and carrot pomace were determined. The fibre contents were found to be higher in the pomace than the carrot slices and in the dried samples than the fresh samples. Also, there was significant difference in the carotenoid and vitamin C content between the fresh and dried samples. The drying time and the drying rate for the samples also vary significantly, the pomace dried faster than the sliced carrots and all the drying took place in the falling rate period. In the colour analysis, lightness and yellowness is higher in the carrot pomace than the carrot, and the mean values for the colour parameters vary significantly between the fresh and dried samples. However, it was observed that, the processing of carrot by juice extraction into carrot pomace increases its fibre contents, its lightness and yellowness.

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