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Comparison of Nutritional and Colour Properties of Fresh and Dried Carrot (*Daucus carota* L.) Slices and Carrot Pomace

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***Abstract*— This study was carried out to compare the nutritional and colour properties of fresh and dried carrot and carrot pomace. Carrot tubers sliced into cubes and some processed by juice extraction into pomace were dried to equilibrium moisture content at a constant temperature of 60°C in an electric convective dryer. The nutritional and colour properties of the samples were determined before and after drying, and compared. It was observed that the fibre contents were higher in the fresh pomace than the fresh carrot, and in the dried samples than the fresh samples. There were significant reductions in carotenoid and vitamin C levels during drying. In the colour analysis, lightness and yellowness were higher in the carrot pomace than the carrot, and the mean values for other colour parameters varied significantly between the fresh and dried samples.**

***Keywords*— Carrot, Colour, Drying, Nutritional, Pomace**

I. INTRODUCTION

Carrot (*Daucus carota* L.) is one of the most important root vegetable crops and is highly nutritious. It is a rich source of β-carotene and contains thiamine, riboflavin, vitamin B-complex and minerals [1]. 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 [2]. It is greatly treasured as food mostly because it is the best source of carotene, a precursor of Vitamin A [3]. Moreover, carrot contains abundant quantities of nutrients and minerals [4], [5].

Carrot is an economically important crop that has become increasingly popular recently due to increased awareness of its nutritional value. Among 39 fruits and vegetables carrots have been ranked 10th in nutritional value [6]. The storage organ (root) of the carrot is the part of the plant that is most often consumed. They are consumed uncooked in salads, steamed or boiled as vegetables and may also be cooked with other vegetables in the preparation of soups and stews [7]. Besides being food, carrot has therapeutic importance as it enhances resistance to blood and eye diseases [8]. Carrots do not supply a significant amount of calories to the human diet, but do supply nutrition in the form of phytochemicals, particularly carotenoids. The greatest nutritional interest in carrots stems from their phytochemical content, but research has also focused on carrots as a source of dietary fibre. Nutrient content of carrots can vary with cultivar [5], season [9], environmental conditions [10], and maturity.

Carrot pomace refers to the wet carrot shavings produced from carrot juice extraction. However, this pomace contains large amounts of valuable compounds such as carotenoids, dietary fibre [11], uronic acids and neutral sugars [12]. During commercial juice processing, 30–50% of carrot is recovered as pomace [13], and up to 50% of the carotene is lost with this pomace [14]. Reference [15] 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%). The by-product of carrot after juice extraction therefore represents a promising source of compounds with bioactive properties that could be explored in the development of food ingredients and dietary supplements [16], [17].

Efforts have been made to utilize carrot pomace in foods such as bread, cake, dressings, pickle, fortified wheat bread [18], preparation of high fibre biscuits [19], and production of functional drinks [20], [21]. Carrot pomace contains 4–5% protein, 8–9% reducing sugar, 5–6% minerals and 37–48% total dietary fibre (on dry weight basis), and carrot products are therefore known to be a good source of dietary fibre [13]. Dried carrot pomace also contains mineral components including iron, zinc, potassium and manganese which can enrich wheat bread mineral composition since wheat is a poor source of microelements [22]. Further, dried carrot pomace contains good quantities of β-carotene and ascorbic acid [23]. Dried carrot pomace can be used to develop exudates and flavours.

The properties of dried vegetables are affected by chemical and physical changes. The effects of chemical changes are mainly evident in sensory characteristics such as colour, taste and aroma, while physical changes affect handling properties such as swelling capacity and cooking time [24]. Maximum retention of β-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 and compare the differences in the nutritional and colour properties of fresh and dried carrot and carrot pomace. In addition, this work was aimed at determining the effect of juice extraction on some nutritional and colour properties of carrot.

II. MATERIALS AND METHODS

A. Experimental Material

Fresh carrot (*Daucus carota* L.) tubers were procured from a local vegetable market in Akure, Nigeria. Carrot tubers were washed in potable water to remove impurities; they were then trimmed with a stainless steel knife and again washed thoroughly with potable water. The carrot tubers were divided into two (2) batches: batch A was sliced into cubes of different sizes and batch B was carrot pomace – this is the by-product obtained after juice extraction from carrot using a juice extractor.

B. Drying Procedure

The initial moisture content of each sample was determined using gravimetry (oven drying at 105°C until no further change in weight was observed) [25]. 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 (wet basis) according to [26], as given in (1):

$$MC = \frac{M_1 - M_2}{M_1} \times 100 \quad (1)$$

where:

MC = moisture content of sample (% wet basis)

M_1 = initial weight of the sample (g)

M_2 = final weight of the sample (g).

40g of each sample was spread in a thin layer on paper carton wrapped with aluminum foil and placed on the tray of the electric convective dryer. The samples were subjected to a constant drying temperature of 60°C [27] and air velocity of 1.2m/s and dried continuously to equilibrium moisture content (EMC).

C. Nutrient Analysis

Nutrient analysis was done to determine the vitamin A (carotenoids), vitamin C and fibre contents. All nutrient analyses were carried out according to the methods prescribed by the Association of Official Analytical Chemists [28]. Fresh samples of carrot and pomace were taken to the laboratory for the nutritional tests and after drying, samples dried to equilibrium moisture content from carrot and pomace were duly labelled and returned to the laboratory for the same tests. Three replicates were obtained per nutrient, per sample (treatment). The values were then subjected to one-factor Analysis of Variance (ANOVA) using the General Linear Model (GLM) procedure. 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).

For vitamin A determination, a 1.0g carrot sample was weighed into 20ml acetone. The mixture was filtered after one hour. Thereafter, 10ml of distilled water was added to the filtrate. The filtrate was then poured into a separating funnel. 5ml 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, and then the lower layer was discarded. The concentration of the upper layer at 440nm was measured, taking the acetone as the blank.

For vitamin C determination, a mixture of 0.05g of 2, 6 dichlorophenol–indophenol dissolved in water was made up to 100ml (with distilled water) and filtered. 0.05g of pure ascorbic acid was then dissolved in 60ml of 20% metaphosphoric acid and made up to 250ml with distilled water. 10ml 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 1ml of the dye solution.

To determine fibre, fritted crucibles were pre-dried at 130 ± 2°C for 30 minutes. The pre-dried crucibles were placed on a balance. 1.0g of carrot sample *(W_1)* was placed into a crucible containing 1.0g celite 545 to simplify filtration. The fibertec hot extraction unit was switched on, and 1.25% sulphuric acid (H_2SO_4) was heated on a hot plate. Using a holder, the crucibles were inserted and locked into position in front of the radiator in the fibertec hot extraction unit, ensuring that the safety latch was engaged. The reflector was placed in front of the crucibles and all values were put to closed position. Cold water tap (1-2L/min) was opened for reflux system and 150ml of preheated 1.25% H_2SO_4 was added into each column as reagent 1. Three drops of n-octanol were added to prevent foaming. The heater was turned on and when the reagents started to boil, the heater control was adjusted to moderate the boiling. The solution reached boiling point after 30 minutes, after which the heater was turned off ending the extraction process.

The valves were placed in vacuum position and a cold water tap was opened to full flow rate for the water suction pump and the start of filtration. Reverse pressure was used to wash the sample three times with hot deionized water. A 30ml portion of water was used and sucked as dry as possible between washings. 150ml of preheated 1.25% NaOH solution was added into each column as the second 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. 25ml of acetone was added to each crucible and the solvent was extracted and filtered out by placing the valve in vacuum position; this process was repeated three (3) times. The crucibles were removed and transferred to

the crucible stand and left at room temperature until the acetone had 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 0.1mg *(W_2)*. The samples were ashed in the crucibles *(W_3)* for at least 3 hours at 525±15°C. Crude fibre was then determined using (2):

$$\% \text{ crude fibre} = \frac{W_2-(W_3+C)}{W_1} \quad (2)$$

where:

W_1 = sample weight (g)
W_2 = crucible + residue weight after drying (g)
W_3 = crucible + residue weight after ashing (g)
C = blank.

D. 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 (lightness/darkness), a (percentage red/green), and b (percentage yellow/blue hue) [29]-[31]. 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 chromameter. Calibration of the chromameter was done using a standard white tile. 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 [32], as given in (3)-(5):

$$\Delta L^* = L^*_{sample} - L^*_{standard} \quad (3)$$

$$\Delta a^* = a^*_{sample} - a^*_{standard} \quad (4)$$

$$\Delta b^* = b^*_{sample} - b^*_{standard} \quad (5)$$

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 using (6), according to [32]:

$$C^*_{standard} = \sqrt{a *^2_{standard} - b *^2_{standard}} \quad (6)$$

Sample chroma values were calculated using (7):

$$C^*_{sample} = \sqrt{a *^2_{sample} - b *^2_{sample}} \quad (7)$$

Change in chroma (*ΔC**) was then determined as given by (8) [32]:

$$\Delta C^* = C^*_{sample} - C^*_{standard} \quad (8)$$

Total colour difference, *ΔE**, was then calculated using (9) [32]:

$$\Delta E^* = \sqrt{\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2}} \quad (9)$$

The hue (*ΔH**) for each sample was then determined from the relationship in (10) [32]:

$$\Delta H^* = \sqrt{\Delta E^{*2} + \Delta L^{*2} + \Delta C^{*2}} \quad (10)$$

III. RESULTS AND DISCUSSION

A. Nutrients

The nutrients analyzed were 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, agreeing with results for higher fibre content of dried samples by [33]. Also the fibre contents were found to be higher in the fresh and dried pomace than the fresh and dried carrot. This could be attributed to concentration due to moisture removal.

Carotenoids and Vitamin C contents in the fresh carrot and pomace samples were significantly higher than in their dried samples; this implies that carotenoids and vitamin C are lost during drying, being heat-sensitive vitamins, agreeing with the findings of [34], who reported a decrease in vitamin A and C contents during the drying of tomato slices. Reference [33] also observed that the total carotenoid content in dried carrot samples decreased irrespective of the drying method used; similar results of decrease in total carotenoids were reported by [35] for mango. The carotenoid content in the pomace was higher while the vitamin C in the pomace was lower than that in the carrot.

TABLE 1: MEAN VARIATION OF NUTRIENTS WITH FRESH AND DRIED CARROT SAMPLES

	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}
Vitamin A (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}

^{a,b,c,d}within the same row, means with different subscripts are significantly different ($P<0.05$)

TABLE 2: DIFFERENCES IN COLOUR INDICATOR MEASUREMENTS FOR FRESH AND DRIED CARROT SAMPLES

	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]

[a,b,c]within the same row, means with different subscripts are significantly different (P<0.05)

B. Colour

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 and pomace. Their mean differences are presented in Table 2.

*L** values were significantly higher for fresh samples than the dried samples, indicating a significant loss of colour during drying. There was also a significant difference between the lightness of the fresh pomace and fresh carrot, as the lightness in the fresh pomace was found to be higher than the fresh carrot. This may be as a result of the juice extracted from the carrot pomace. The *a** (redness) value of the fresh carrot was higher than for the fresh pomace, while the *b** (yellowness) value of the fresh pomace was higher than for the fresh carrot. There were significant differences between the fresh and dried samples for all the colour indicators.

The calculated values of chroma change (Δ*C**), colour change (Δ*E**) and hue (Δ*H**) for the dried carrot and pomace samples were also analyzed in triplicate. The results are 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 significant difference between the chroma values for 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. The mean hue values also varied significantly between the fresh and dried samples.

TABLE 3: DIFFERENCES IN CALCULATED COLOUR PARAMETERS FOR FRESH AND DRIED CARROT SAMPLES

	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]

[a,b,c,d]within the same row, means with different subscripts are significantly different (P<0.05)

IV. CONCLUSION

The nutritional and colour properties of fresh and dried carrot and carrot pomace were determined. The fibre contents were found to be higher in the fresh pomace than in the fresh carrot, and in the dried samples than the fresh samples. There were significant losses in carotenoid and vitamin C contents during drying. For colour, lightness and yellowness were significantly higher in the fresh carrot pomace than in the fresh carrot, and the mean values for the colour parameters varied significantly between the fresh and dried samples. It was observed that the processing of carrot by juice extraction into carrot pomace increases its fibre content and lightens its colour.

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