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EFFECT OF CARROT DRYING CONDITIONS ON SURFACE CAROTENE CONTENT AND DRYING CURVE

El-Shehawy, Sh. M. * and H. E. El-Mashad**
*** Food Industries Dept., Fac. of Agriculture, Mansoura University, Egypt**
**** Agric. Engineering Dept., Fac. of Agric., Mansoura University, Egypt**
Post box: 35516, El-Mansoura city, Egypt
Corresponding author. Tel.: 0020103481845; Fax: 0020502221688
E-mail address: yshmtu10@mans.edu.eg (Sh.M.M. El-Shehawy).

ABSTRACT

Because of the seasonal character of many fruits and vegetables, some affordable means of preserving in farm or home garden produce is necessary. This will prevent waste during the harvest season and extend the time, which food can be used, increasing the possibility of a year-round supply. Artificial drying, or simply laying the food under the sun is a popular traditional method of preserving fruits and vegetables in African and Asian countries. In areas where there is a shortage of water, it may be the only means of food preservation. However, excessive loss of carotenoids, which play an important role in human nutrition as natural antioxidants, can occur. So, this manuscript was carried out to show effect of carrot drying conditions such as, carrot shape (cubes, slices and flakes), blanching and drying temperatures (50, 60 and 70°C) on surface carotene content and drying curve. From obtained results, it could be concluded that studied drying conditions had a valuable effect on carotene content and drying curve. Also, calculated carrot drying and carotene equations will help to expect moisture content and surface carotene content after specific time at different temperatures.
Keywords: Drying temperatures, carrot shapes, blanching, drying curves and carotene content.

INTRODUCTION

Carrot is one of the most commonly used vegetables for human nutrition due to high vitamin and fiber content. Since higher temperature causes wilt and have a poor appearance on the carrots, refrigeration and controlled atmosphere storage have been used (Negi and Roy, 2000).

Alternatively, the keeping ability of carrot can be enhanced by drying and subsequent storage. Drying operations are important steps in food processing industry. Drying is one of the oldest methods of food preservation, and it represents a very important aspect of food processing. Sun drying is the most common method used to preserve agricultural products in most tropical countries. However, this technique is extremely weather dependent, and has the problems of contamination with dust, soil, sand particles and insects, and being weather dependent. Also, the required drying time can be quite long. Therefore, using solar and hot-air dryers, which are far more rapid, providing uniformity and hygiene are inevitable for industrial food drying processes (Diamante and Munro, 1993; Ratti and Mujumdar, 1997).

Several studies have been conducted to the influence of some process parameters such as temperature, sample thickness and air-flow rate, etc.

Cordova-Quiroz, *et al.* (1996) investigated the effect of carrot slices with 0.5 cm thickness and 0.5–1.0 m/s of air-flow rate on the drying kinetics.

Carotenoids have attracted the interest of researchers from diverse fields including chemistry, biochemistry, biology, food science and technology, medicine, pharmacy, and nutrition for more than a century, and these fascinating compounds continue to be intensely investigated. Carotenoids are widely distributed natural pigments responsible for the yellow, orange, and red colors of fruits, roots, flowers, fish, invertebrates, and birds. They invariably occur in the chloroplasts of higher plants, although in this photosynthetic tissue their color is masked by that of chlorophyll. They are also found in algae, bacteria, molds, and yeasts. It is estimated that nature annually produces about 100 million tons of carotenoids (Delia, 1997).

Two root crops, carrot and yellow-to-orange sweet potato, are available throughout the world and are important sources of carotenoids. Widely varying provitamin A concentrations have been reported, however, for both roots. Carrot, from which the carotenoids derived their name is the traditional example of a provitamin A rich food, and is among the most analyzed food in terms of carotenoids (Reddy *et al.*, 1995).

The average of á-carotene level in carrot varied from 5.3 µg/g (Finland) (Heinonen *et al.*, 1989) to 106 µg/g in the U.S. (Khachik and Beecher, 1987), while â-carotene ranged from 36 µg/g (U.S.) (Bushway *et al.* 1986) to 182 µg/g (U.S.) (Khachik and Beecher 1987). These lower and upper limits were obtained by HPLC. Most of the investigations placed the concentration of á-carotene at about 30 µg/g and â-carotene at 60 to 70 µg/g. Heinonen (1990) determined the provitamin A content of 19 cultivars of orange carrot and found the á-carotene varied from 22 to 49 µg/g, â-carotene from 46 to 103 µg/g, and ã-carotene from 6.3 to 27 µg/g. Simon and Wolff (1987) studied seven typical and dark orange carrots; the total carotene content, consisting mostly of â-carotene and á-carotene, ranged from 63 to 548 µg/g.

On the other side, USDA, (2009) reported that raw carrot (88.29% moisture) contained 8.28 and 3.48 mg/100g β and α-carotene, respectively while, dehydrated carrot (4% moisture) had 33.95 and 14.25 mg/100g of them, respectively.

The effects of blanching and predrying treatments on the stability of carotenoids in papaya and pineapple were examined by Sian and Ishak (1991). Carotenoids progressively decreased in both fruits as blanching temperature and time increased. After drying, the unblanched papaya and pineapple retained the highest carotenoid content. Pigment retention after blanching or drying was lower in the pineapple than in the papaya. Sulfur dioxide prevented carotenoids from oxidation. Carotenoids were also more protected when more moisture was retained by adding glycerol and sugar.

Carotene levels in vacuum dried (16 hours at 55°C, 15 inch Hg) carrot, broccoli, and spinach were significantly greater than those of the microwave dried (high heat setting, 750 watts) vegetables (Park, 1987). Park concluded, nonetheless, that dehydration, regardless of drying method, significantly reduced the carotene content of these vegetables. In contrast, in industrial dehydration (hot air drying at 65°C) and lyophilization (freezing at -30°C and lyophilization at -10°C) of spinach previously immersed in salt and bicarbonate solutions, only a 12 percent loss of â-carotene occurred in both drying methods (Ramos and Rodriguez-Amaya, 1993). No loss in â-carotene was observed in the industrial dehydration (hot air drying at 70-80°C) of steam blanched carrots, but lyophilization brought about a 16 percent decrease. These losses are small, considering the drastic processing treatment involved in dehydration and the greater exposure to oxygen. Calculation of losses was done on the dry weight basis for spinach and on a water insoluble solid basis for carrot, because the high soluble solid leaching in carrot resulted in more than 100 percent retention of â-carotene when dry weight was used.

No one I believe, try to follow up surface carotenoids changes via drying time at different temperatures. So, the main goal of such study to investigate the effect of carrot drying conditions such as, carrot shape (cubes, slices and flakes), blanching and temperatures (50, 60 and 70°C) on surface carotene content and drying curve. As well as, trying to put an equation describe the relationship between surface carotenoids content and drying time at different carrot drying parameters.

MATERIALS AND METHODS

Materials:

Fresh carrot (*Daucus carota* L.) were collected from Posat village farms, Mansoura, Egypt and stored at 4°C. Before starting each drying experiment, carrots were peeled and cut into 1 cm^3 cubes, 5 mm thickness slices and flakes.

Solvents and other reagents were purchased from El-Gomhoria for chemicals company, Mansoura, Egypt.

Methods:

Blanching:

Carrot shapes were individually blanched in boiled water (100°C) for 3 Min. and tested for oxidation enzymes using H_2O_2.

Experimental set-up:

Air drying oven (Officine specializzate, GARBUIO, essiccatioi, TREVISO, ITALY) was used for carrot drying (3 shapes blanched or not) at 50, 60 and 70°C. The inlet air that was used to dry the sample was heated up to the desired temperature by an electric heater. The sample was placed on a tray made of a metal screen as thin layer. The air velocity over the drying tray was fixed at 2 m/s.

Chemical analysis:

Moisture content was determined according to AOAC, (2000). Surface carotene content (as β-carotene) was calorimetrically estimated according to the method described by Srivastava and Kumar, (2006) using authentic β-carotene as standard reference.

Mathematical analysis:

Mathematical modelling was done using Microsoft® office Excel (2003) for windows.

Statistical analysis (ANOVA and T test) were done using SPSS (2003) version 12 program for windows.

RESULTS AND DISCUSSION

1- Carrot drying curves and equations:

Data illustrated in figures (1, 2 and 3) show carrot drying curves as treated with various drying conditions such as carrot shapes (cubes, slices and flakes), blanching or non and drying temperatures (50, 60 and 70°C).

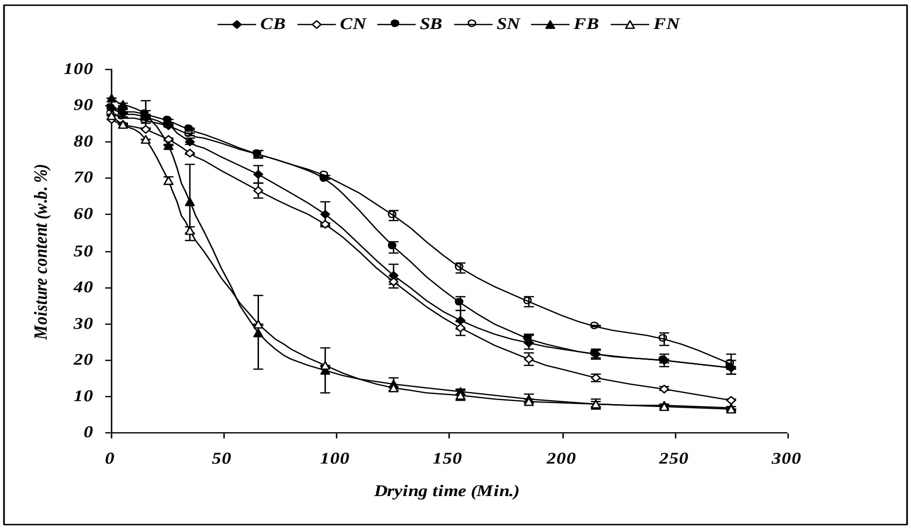

Fig. (1): Drying curves of carrot subjected to various drying treatments at 50°C.

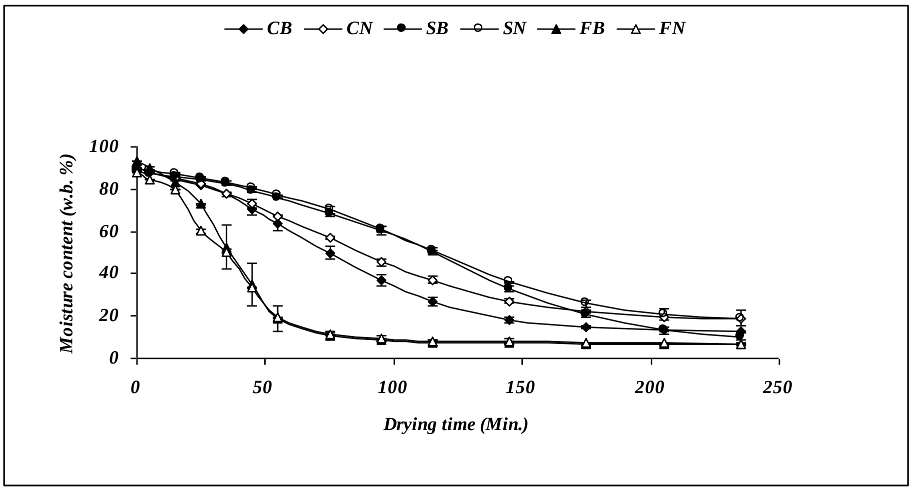

Fig. (2): Drying curves of carrot subjected to various drying treatments at 60°C.

Drying curves are affected by many factors which rise or decrease drying rates. For example, drying temperatures, shapes, relative humidity, air velocity, dryer types, food pieces thickness and drying times.

Obtained results ensured that the increase of drying temperature was happen, the increase of drying rate was noticed. It could be easily seen that all carrot treatments at higher temperatures were dried faster than those at lower ones (70>60>50°C). As carrot shapes, flake drying rates were in the first order followed by cubes, then slices came in the third order. However, carrot slices were in the second order on 70°C run. This trend was sure attributed to the high surface area in carrot pieces (Cordova-Quiroz, *et al.*, 1996).

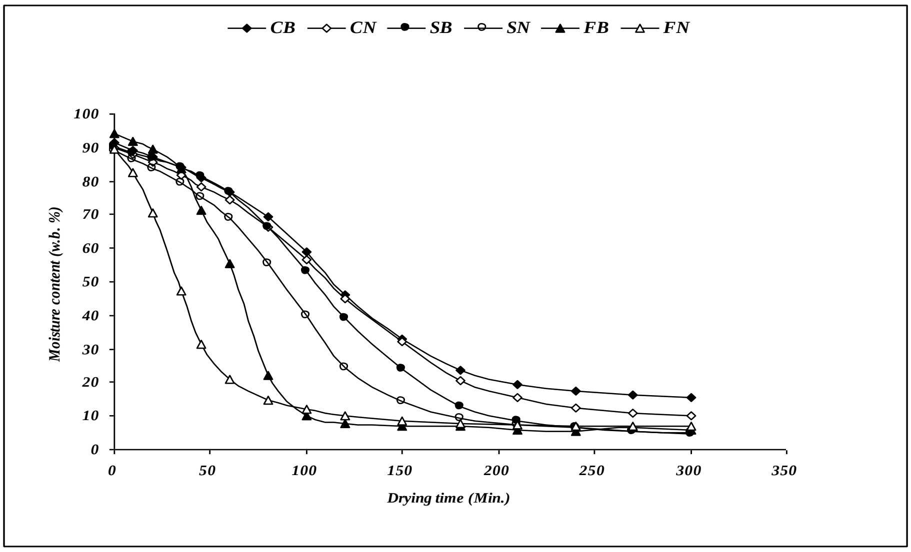

Fig. (3): Drying curves of carrot subjected to various drying treatments at 70°C.

Drying kinetics of carrots dried in a spout-fluidized bed has been studied. It was observed that the temperature of air did not influenced the shape of drying curves and all carrot samples dried in a spout-fluidized drying showed only the falling rate period. As it was expected, the higher air temperatures were applied the higher drying rates were observed (Zielinska and Markowski, 2010).

Concerning blanching treatment, it could affect on drying rates from two point of view. The first, it could rise drying rate by heat tissues tenderization and consequently, moisture evaporation will be easier. It is believed that the aspects responsible for such effect of blanching are: (i) change in physical properties of the tissue, such as destruction of the cell membranes by heat; and (ii) loss of soluble solids.

During heat treatment, proteins in cell membranes are denaturated above a certain temperature so that membranes become porous. Cell membranes are then unable to maintain cell turgor which facilitates the water removal (Lewicki, 2006).

The second, it could decrease drying rates by rising moisture content in carrot treatments because of water absorption by carrot tissues. So, blanching treatment sometimes help to increase drying rates as shown in CB treatment at 60°C and often, decrease drying rates as in the rest of treatments.

Drying curves could be divided into two stages in all carrot treatments but, there is a special case in carrot flake treatments where, the first stage showed a sharp decrease in moisture content and the second, moisture content slightly decreased or was constant. The pervious observation could be easily explained as the high surface area was in flakes and thus, water evaporation was higher. In carrot cubes and slices, the first stage showed a gradual decrease then, moisture contents were nearly constant.

Shorter drying time of carrot cubes and increased drying rates are the beneficial effects of applied methods of blanching. The effect of blanching in boiling water for 6 Min. is the strongest and in boiling 5% brine solution for 3 Min, is the weakest. Applied methods of blanching have no effect on the volumetric shrinkage (Górnicki and Kaleta, 2007).

The previous discussion stand on technological view, while as for mathematical side, Table (1) show carrot treatments drying equations. Many equations were applied but, linear equation was the best because the determining coefficient (**R^2**) was the higher and mathematical models were compatible with technological trend.

Table (1): Carrot treatments drying equations:

Code	°C	Carrot shapes	Blanching	Mathematical equations	R^2	F test	T test
CN50	50°C	Cubes	without	y= 85.995 – 0.315x	0.975	424.11**	-20.59**
CB50			with	y= 88.434 – 0.299x	0.957	242.40**	-15.57**
SN50		Slices	without	y= 90.629 – 0.270x	0.985	731.44**	-27.05**
SB50			with	y= 91.628 – 0.303x	0.963	288.80**	-16.99**
FN50		Flakes	without	y= 70.706 – 0.305x	0.781	39.15**	-6.26**
FB50			with	y= 76.197 – 0.331x	0.767	36.29**	-6.02**
CN60	60°C	Cubes	without	y= 86.837 – 0.347x	0.943	199.06**	-14.11**
CB60			with	y= 85.558 – 0.383x	0.916	130.99**	-11.45**
SN60		Slices	without	y= 92.756 – 0.345x	0.978	534.95**	-23.13**
SB60			with	y= 92.999 – 0.377x	0.982	660.37**	-25.70**
FN60		Flakes	without	y= 63.254 – 0.336x	0.649	22.19**	-4.71**
FB60			with	y= 67.877 – 0.368x	0.648	22.07**	-4.70**
CN70	70°C	Cubes	without	y= 88.960 – 0.311x	0.951	253.79**	-15.93**
CB70			with	y= 90.179 – 0.299x	0.937	194.35**	-13.94**
SN70		Slices	without	y= 83.143 – 0.328x	0.883	97.98**	-9.90**
SB70			with	y= 90.307 – 0.344x	0.932	178.01**	-13.34**
FN70		Flakes	without	y= 56.123 – 0.230x	0.586	18.42**	-4.29**
FB70			with	y= 76.687 – 0.322x	0.705	31.13**	-5.58**

Where, y means moisture content (%) and x means drying time (Min.).
**** Significant at p > 0.01.**

These studied equations could help us to predict drying time and drying ratio at different temperatures and carrot shapes. Determination coefficients were high in all equations, which it ranged from 0.586 in FN70 treatment to

0.985 in SN50 treatment and this ensured that all calculated equations were strong enough to represent the actual data.

From previous results, it could be observed that moisture content decrease (%) per time unit (Min.) was higher in dried blanched carrot treatments in all drying equations except in case of carrot cubes at 50°C and 70°C. Where, it was -0.315%/Min. and -0.299%/Min. in non-blanched and blanched cubes dried at 50°C, respectively. Also, moisture content decrease (%) per time unit (Min.) ranged from -0.230%/Min. (FN70) to 0.383%/Min. (CB60). Concerning carrot shapes, moisture content rates had no clear trend but it could said that flakes had the higher ones and slices had the least ones. These observations were in good agreement with technological discussion.

F test (analysis of variance) was carried out to indicate that there are significant differences between drying equations or not and it showed significant differences between all drying equation at $P > 0.01$, where F value ranged from 18.42 (FN70) to 731.44 (SN50).

T test was done to indicate that there are significant differences between β values in drying equation or not. T value ranged from -4.29 (FN70) to -27.05 (SN50). There were significant differences between all β values (x factor) at $p > 0.01$.

2- Surface carotene content changes via drying time:

Surface carotene contents (as β-carotene) in all carrot treatments were studied against drying time at different temperatures 50°C (Fig. 4), 60°C (Fig. 5) and 70°C (Fig. 6). Carotene content (mg/100g) was determined according to the method described in materials and methods in carrot pieces as they were dried without mincing or homogenizing. So, studied carotene content did not express the actual carotene content in carrot treatments and could be called surface carotene content. Surface carotene content reflected effect of drying temperatures and pretreatment in every carrot shape.

From obtained curves, it could be seen that carrot flakes had the highest surface carotene content followed by carrot slices and then carrot cubes came at the end. Carrot flakes had high surface area enough to make carotene extraction by used solvent easier.

As blanching treatment, surface carotene content in all non blanched treatment was higher than in blanched treatments. For example, at 50°C run, it represented 77.97 and 52.14 mg/100g (Fig. 4) in non blanched and blanched carrot flakes at zero time of drying, respectively. Some carotene content loss were observed during carrot blanching process.

Concerning drying time, surface carotene content of all carrot treatments significantly increased until the end of sampling at 180 Min. For example, at 50°C run, blanched carrot slices carotene contents were 22.36, 20.84, 294.95 and 362.18 mg/100g at 0, 60, 120 and 180 Min. of drying, respectively. The same trend was observed in all other temperature runs but with differences in carotene values.

These increases in carotene content could be attributed to three reasons: (i) moisture content decreasing in all treatments during drying at different temperatures and consequently increasing of total solids content including pigments, (ii) Carotene transportation from the inner layers to outer layers caused by high concentration in outer layers (Osmotic) and (iii) solvent extraction efficiency was in an inverse relationship with moisture content in extracted materials. So, the decrease of moisture content was noticed, the increasing of solvent extraction efficiency was observed.

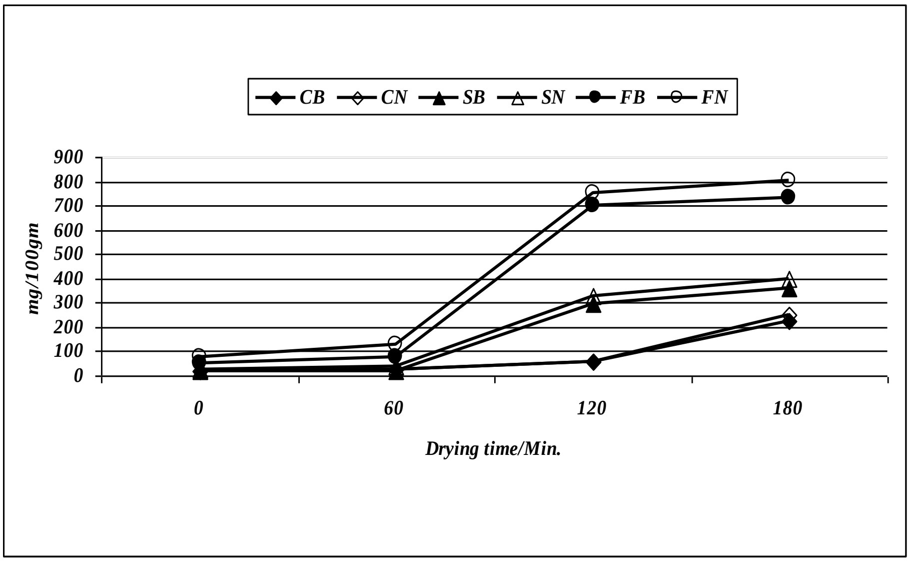

Fig. (4): Effect of drying process at 50°C on surface carotene (mg/100g) in carrot treatments.

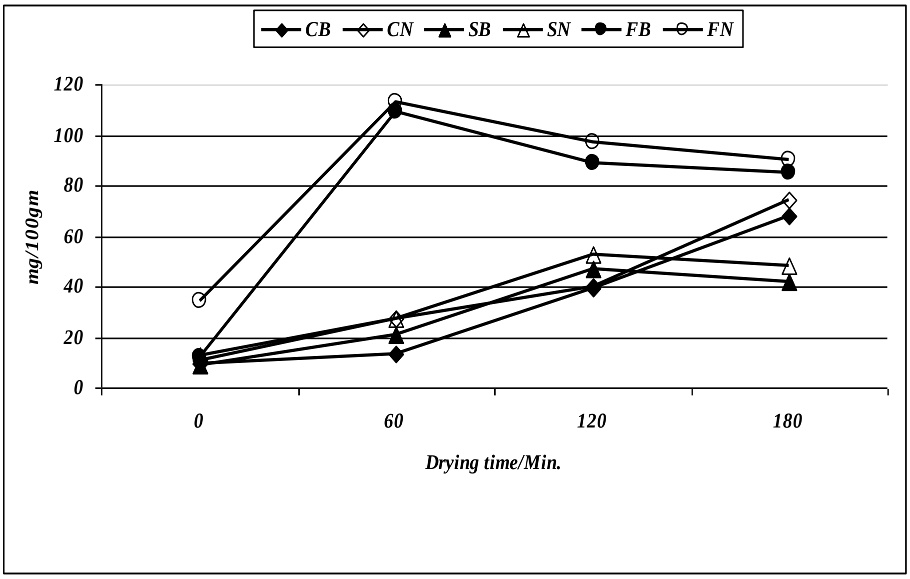

Fig. (5): Effect of drying process at 60°C on surface carotene (mg/100g) in carrot treatments.

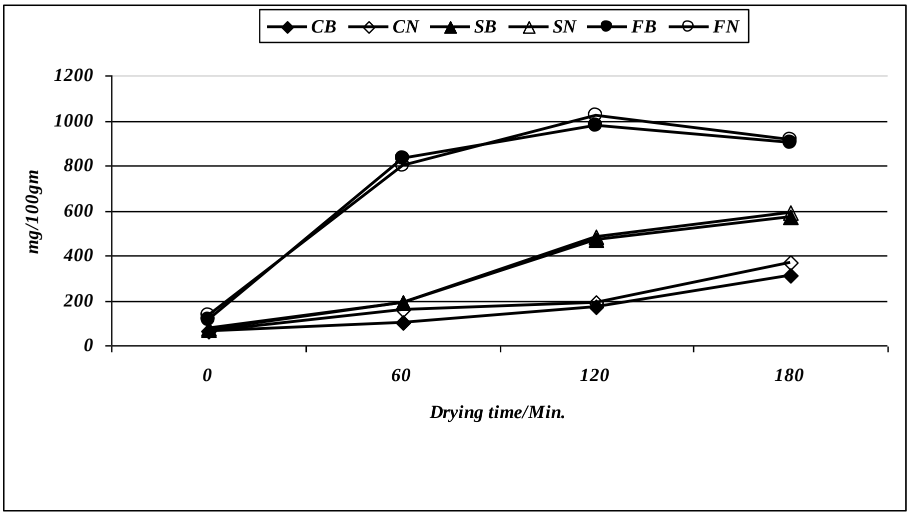

Fig. (6): Effect of drying process at 70°C (mg/100g) on surface carotene in carrot treatments.

As mathematical modeling, Table (2) show surface carotene content (mg/100g) via drying time (Min.) equations of different carrot treatments. Many equations were applied but, linear equation (regression) was the best because the determining coefficient (R^2) was the higher and the model agreed with technological view. R^2 varied from 0.329 in FN60 treatment to 0.965 in SB70 treatment. There were no significant differences between most of drying equations, where F value ranged from 0.981 (FN60) to 12.17 (FN50). But, there were significant differences between some equations such as SN50, SB50, CN60, CB60 and CB70 at P> 0.05. While, significant differences were noticed between CN70, SN70 and SB70 equations at p> 0.01.

β value (x factor) in obtained equations (Table 2) referred to surface carotene content increase (mg/100g) per time unit (Min.). It ranged from 0.210 mg/Min. to 4.661mg/Min. in SB60 and FN50 treatments, respectively. As carrot shapes, surface carotene content change via time unit was the highest in flakes followed by slices then cubes came at the third order in different studied temperatures. For instance, carotene change rates were 1.194, 2.351 and 4.661 mg/Min. in CN50, SN50 and FN50, respectively. This note may be due to the high surface area in flakes and thus effect of drying temperatures or any variable will be higher.

Concerning blanching treatment, it could easily noticed that blanching treatment reduced surface carotene change per time unit. This observation ensure previous results in surface carotene curves and sure attributed to some carotene losses during blanching treatment (100°C for 3 Min.). There were no significant effect of drying temperatures (50, 60 and 70°C) on surface carotene changes per time unit. T test had the same significant differences shown in F test but between β values in the presented equations.

These studied equations could help us to predict surface carotene content at different temperatures and carrot shapes.

Table (2): Surface carotene content (mg/100g) via drying time (Min.) equations of different carrot treatments:

Code	°C	Carrot shapes	Blanching	Mathematical equations	R^2	F test	T test
CN50	50°C	Cubes	Without	y=-18.079 +1.194x	0.729	5.38	2.32
CB50			With	y=-12.655 +1.053x	0.742	5.74	2.40
SN50		Slices	Without	y=-14.403 +2.351x	0.887	15.71*	3.96*
SB50			With	y=-18.983 +2.155x	0.867	13.08*	3.62*
FN50		Flakes	Without	y=20.993 +4.661x	0.859	12.17	3.49
FB50			With	y=-9.730 +4.457x	0.836	10.20	3.19
CN60	60°C	Cubes	Without	y=7.536 + 0.339x	0.947	35.67*	5.97*
CB60			With	y=2.55 + 0.333x	0.918	22.51*	4.74*
SN60		Slices	Without	y=15.383 + 0.220x	0.827	9.55	3.09
SB60			With	y=10.832 + 0.210x	0.819	9.07	3.01
FN60		Flakes	Without	y=60.884 + 0.253x	0.329	0.981	0.990
FB60			With	y=44.188 + 0.330x	0.364	1.14	1.07
CN70	70°C	Cubes	Without	y=64.415 + 1.299x	0.964	54.31**	7.37**
CB70			With	y=37.677 + 1.368x	0.924	24.26*	4.93*
SN70		Slices	Without	y=59.842 + 3.064x	0.961	48.74**	6.98**
SB70			With	y=57.743 + 2.966x	0.965	54.43**	7.38**
FN70		Flakes	Without	y=335.595+ 4.242x	0.683	4.30	2.07
FB70			With	y=327.93 + 4.183x	0.658	3.84	1.96

Where, y means surface carotene (mg/100g) and x means drying time (Min.).
**** Significant at p > 0.01.**
*** Significant at p > 0.05.**

Conclusion

In conclusion, the present study has clearly indicated that blanching process causes important losses of carotene and therefore should be controlled as possible. Carrot drying curves with various treatments were documented form both technological and mathematical view. Also, carrot drying and surface carotene content models could be used to predict either moisture content, drying ratio or surface carotene contents with high confidence.

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تأثير ظروف تجفيف الجزر على محتوى الكاروتين و منحنى التجفيف

شادي محمد الشهاوي* و حامد الموافي المشد**
*** قسم الصناعات الغذائية – كلية الزراعة – جامعة المنصورة – مصر**
**** قسم الهندسة الزراعية – كلية الزراعة – جامعة المنصورة – مصر**

هنالك ضرورة لإستخدام بعض وسائل حفظ الخضروات و الفواكه سواء في المزرعة أو الحدائق حيث أنها تتسم بالموسمية. تمنع تلك الوسائل الفاقد أثناء موسم الحصاد كما أنها تطيل من فترة إستخدام الغذاء و تزيد من احتمالية توفر هذا الغذاء على مدار العام. و يعد التجفيف الطبيعي أو الصناعي طريقة حفظ تقليدية للأغذية و منتشرة في كلاً من أفريقيا و أسيا خاصةً في المناطق التي تعاني نقصاً في المياه. و مع ذلك يحدث فقد واضح في الكاروتينات التي تلعب دوراً هاماً في تغذية الإنسان كمضادات أكسدة. لذا تم تنفيذ هذه الدراسة لتوضيح تأثير ظروف تجفيف الجزر مثل شكل الجزر (مكعبات ، حلقات و مبشور) ، و عملية السلق ، و درجات الحرارة (٥٠°م ، ٦٠°م و ٧٠°م) على محتوى الكاروتينات و منحنى التجفيف. أشارت النتائج إلى أن ظروف التجفيف تحت الدراسة تؤثر بوضوح على محتوى الكاروتين و منحنى التجفيف. كذلك أمكن عمل معادلات تساعد في توقع نسبة الرطوبة و محتوى الكاروتين السطحي في الجزر بعد زمن محدد عند مختلف درجات الحرارة.

قام بتحكيم البحث

أ.د /أحمد عزت منصور قاسم	**كلية الزراعة – جامعة المنصورة**
أ.د /جميل محمد حبيب	**كلية التربية النوعية – جامعة طنطا**