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Blanching and Drying Behavior of *Dioscorea schimperiana* and Impact on Cellular Exchanges and on Calcium, Ascorbic Acid and β-carotene Contents

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ABSTRACT

The influence of blanching parameters (time and temperature), variety and yam thickness on cellular exchanges and on calcium, ascorbic acid and β-carotene contents during blanching and/or subsequent drying was investigated. Yam slices (2, 3 and 4 mm thickness) of the yellow and orange variety of *D. schimperiana* were blanched in hot water at 70 and 100°C for 0 to 60 sec in order to study the cellular exchange during blanching. Kinetic of calcium loss was determined during blanching at 100°C. Yams slices of the orange variety blanched at 100°C for one minute were dried at 50°C in a cross flow cabinet dryer. Losses in β-carotene and ascorbic acid were calculated after one minute of blanching at 100°C and along the drying process. The results show a strong intraspecific variability in cellular exchange during blanching. Blanching in hot water at 100°C result in a higher loss in calcium, β-carotene and ascorbic acid. These losses continue during subsequent drying. The moisture diffusivity during drying of blanched slices varied from 1.07×10^{-10} (4 mm) to 4.33×10^{-11} (2 mm). Twenty six to fifty percent of the β-carotene and more than 50% of ascorbic acid were loss during blanching depending upon slices thickness. Blanching is the limiting factor in β-carotene and ascorbic acid loss during blanching and subsequent air drying. Blanching parameters (temperature and time), slices thickness and variety influenced cellular exchanges and losses in calcium, β-carotene and ascorbic acid.

Keys words: Yam slices, variety, thickness, diffusivity

INTRODUCTION

Disocorea schimperiana is one of the eight yam species commonly grown and consumed in Cameroon. It is rich in protein, calcium, copper and zinc. It is also a source of carotenoids and carotenoids provitamins A are the major constituent (Gouado *et al*., 2007). Despite these nutritional qualities, this yam is in away of disappearance in Cameroon. In the past, it was cultivated in many regions but now, it area of culture is restricted to the West and North West region (Dumont *et al*., 1994). The high nutritional potential of this yam justifies a need of valorization and development not only for local needs but also for the improvement of the nutritional statute of population and for the food security in general.

Dioscorea schimperiana is generally consumes after boiling in water during the harvest periods (December to January) and as pounded dried yams during the off season period or in time of

scarcity (Bell and Favier, 1981). Drying of *Dioscorea schimperiana* is a traditional process generally used to extend the self life and to improve the organoleptics qualities of the yam. Processing of *D. schimperiana* yam in dried yam then in pounded yams implies a double cooking of small yam discs (3 mm thickness on average and 2 to 8 cm diameter) and an intermediate long drying time (7 to 8 days) in sun or on hurdles. Bell and Favier (1981) stated that this traditional process lead to a high nutrients losses. Proteins and ash losses ranged between 4 to 14% and 33 to 64%, respectively. Losses in thiamin and riboflavin were 71 to 83% and 65 to 81%, respectively. Sun drying it self generated 59 to 71% of niacin losses. Niacin is a thermostable vitamin less sensitive to heat. This implies that thermosensibles vitamins such as ascorbic acid and β-carotene would be entirely lost. According to Bell and Favier (1981), an appropriate air drying and processing of *Dioscorea schimperiana* into flour could be a means of reducing the drying time and nutritional losses. Studies on local techniques of yam flour production reveled that precooking is a crucial step but the resulting cooking products are generally characterized by a browning color due to enzymatic oxidation of polyphenols (Ige and Akintude, 1981; Akissoe *et al.*, 2005). Reduction of yam size as small thickness discs or short sticks before blanching in hot water reduce the drying time, limit browning reaction and improve the color of the resulting cooking products (Hounhouigan *et al.*, 2000). Color is certainly an attribute determining the consumer's choice but the nutritional quality is also determinant for health. During blanching, water diffuses by osmosis through the cellular membranes and the temperature of the hot water can induce modifications in cell membrane structure. This could have an influence on matter transfer and on nutrients contents (water-soluble and thermosensibles nutrients) during blanching and/or subsequent drying of the food material. Carotenoids or ascorbic acid are lost during blanching and/or drying (Pinheiro-Santhana *et al.*, 1998; Cinar, 2004; Gebczynski, 2006) and calcium is an example of minerals that is highly loss during this process. Therefore, blanching conditions should be controlled in order to improve the color of the products and to maintain also the nutritional quality. To the best of our knowledge, no study has been carried out to determine the influence of blanching parameter on the nutritional quality of *D. schimperiana*.

We carried out this study to determine the influence of the processing parameters: slices thickness, temperature and blanching time on cellular exchanges, calcium and β-carotene contents during blanching and on ascorbic acid and β-carotene during the subsequent air drying of *D. schimperiana*.

MATERIALS AND METHODS

Yellow and orange cultivar of *D. schimperiana*, purchased (December, 2006) from local market (Bafoussam, Cameroon), were peeled and slice in order to obtain rings of 2, 3 and 4 mm thickness, with an average diameter of 3 cm.

Blanching: Blanching experiments were performed as described previously by Leng *et al.* (1997). Yam sample were placed in a wire basket and immersed into water bath (Büchi B-490) containing deionized water with the ratio of 10 g of slices per one liter of water. Blanching was performed at 70 and 100°C for 0 to 60 sec. After a given time, the slice were removed from hot water, immediately cooled in water and drained. The moisture at the surface of sample was dried with filter paper. The sample was coated on the aluminum paper and stored at -18°C until analyzed.

Drying

Drying experiment: Drying experiments were performed as described previously by Leng *et al.* (1997). Blanched yams slices were placed in simple an aerated layers on pre-weighed drying trays

and dried at 50°C in a cross flow cabinet dryer (Binder, FDL 115), with an air flow of 24 $m^3 h^{-1}$. Drying trays were periodically weighed all along the drying process. For each sample, drying experiment was conducted in triplicate and from the three values of the tray weight, average of sample moisture was determined as a function of time.

Theoretical consideration of water transfer during drying: The method of slopes was used in the estimation of effective moisture diffusivity of yam slices at corresponding moisture contents. Yam slices were considered as an infinite slab because the thickness of the slices (4 mm) was much less than its diameter (30 mm). The moisture diffusivity (D) for an infinite slab was therefore, calculated by the simplified equation of Henderson and Perry (1976) and Perry *et al.* (1984), expressing the removable moisture ratio (H_r) of sample during drying (Sankat *et al.*, 1996). The equation (Eq. 1) assumes the Fickian diffusion model and the analytical solution proposed by Crank (1975).

$$H_r = \frac{H_t - H_e}{H_0 - H_e} = \frac{8}{\pi^2}\exp\left[\frac{\pi^2 Dt}{4L_0^{\ 2}}\right] = A.\exp(-kt) \quad (1)$$

where, H_t (g $[H_2O]$ g^{-1}DM) is the time dependent moisture content of the sample; H_0 is the initial moisture content of the sample; H_e is the equilibrium moisture content (at the end of the drying process); L*o* (m) is the slab half thickness, D ($m^2 sec^{-1}$) is the apparent moisture diffusivity; t (sec) is the drying time; k (sec^{-1}) is the drying constant obtained from the plot of ln H_r vs. t.

For a given value of H_r (H is therefore know), the theoretical value of $((D\times t)/L_0^2)$ is calculated from the linear regression relationship of the drying data i.e. ln H_r vs t. Then D is obtained from

$$D = \frac{\left(D_t/L_0^{\ 2}\right)_{th}}{\left(t/L_0^{\ 2}\right)_{exp}} \quad (2)$$

where, subscripts th and exp refer to theoretical and experimental values, respectively.

Physico-chemical analyses

Blanching

Study of cellular exchanges during blanching: The study of cellular exchange during blanching was done by measuring the Water Holding Capacity (WHC) directly after the slices were removed from hot water, immediately cooled in deionized water and drained.

Water holding capacity: Water Holding Capacity (WHC) was defined as the ability of the blanched yam to retain it own and/or added water during application of a force. Expressible moisture was related to WHC as the release of free water from yam under application of force as described by Jauregui *et al.* (1981). About 0.5 g of yam was coated with filter paper (Whatman n°3) then centrifuged at 4000 rpm min^{-1} for 30 min. The WHC was defined as the expressive moisture calculated by the following Eq:

$$\% \text{ expressible water} = \frac{M_1 - M_2}{M_1}$$

M_1 and M_2 are the sample weight before and after centrifugation respectively.

Calcium determination: Calcium contents of yam samples after blanching were determined by atomic absorption spectroscopy (Buck Model 200 A) using Association of Official Analytical Chemist (AOAC) approved Method 968.08 (Wardlaw, 1997).

Drying

Moisture, β-carotene and ascorbic acid determination: Moisture content of dried yam sample was determined using the gravimetrical method (AOAC, 1990; Demasse Mawamba *et al.*, 2009). β-carotene and ascorbic acid contents of blanched yam samples were determined all along the drying process, using the De Ritter and Purcell (1981) method for β-carotene determination and the 2,6 diclorophenolindophenol method for ascorbic acid determination (AOAC, 1991; Demasse Mawamba *et al.*, 2009).

Statistical analysis: All the measurements were carried out in triplicate and data obtained were subjected to analysis of variance to evaluate the effect of different parameters on the response. Least significant difference test (LSD<0.05) was used to classify these factors whenever there was a significant difference. All these analyses were carried out using the XLSTAT 6.1.9 software.

RESULT

Water holding capacity: Figure 1 shows the percentage of expressive water during blanching of the yellow and orange variety of *D. schimperiana*. The percentage of expressive water of 2 and 4 mm slices thickness of the orange and yellow variety blanching at 70°C increases significantly at the beginning (0 to 45 min) of the process and decreases thereafter (Fig.1). The percentage of expressive water of 2 mm thickness slices of the orange variety and 4mm thickness slices of the yellow variety during blanching at 100°C evolves irregular. Theses values increase significantly at the beginning of the blanching treatment (0 to 30 min for the yellow variety and 0 to 45 min for the orange variety) then decrease significantly after 55 min of treatment and increase then after. An observation of the values of the percentage of expressive water at 70 and 100°C shows that the yellow variety yam slices have high and comparable percentages of expressive water during blanching at 70 and 100°C whereas, the percentages of expressive water of the orange variety yam slices decrease with the increase in temperature from 70 to 100°C.

Loss in calcium during blanching: Losses in calcium were calculated as the difference between the total amount of the element found in the raw sample and the total amount found in the blanched sample. The results were calculated for each individual sampling and averaged. Losses in calcium (Fig. 2) during blanching at 100°C of the yellow and orange variety of *D. schimperiana* are expressed as g g^{-1} DM where DM refers to the dry matter. The kinetics of calcium loss phenomenon (Fig. 2) is characterized by a rapid phase at the beginning of the blanching process (0 to 20 sec) followed by a stabilization phase. Loss in calcium during blanching

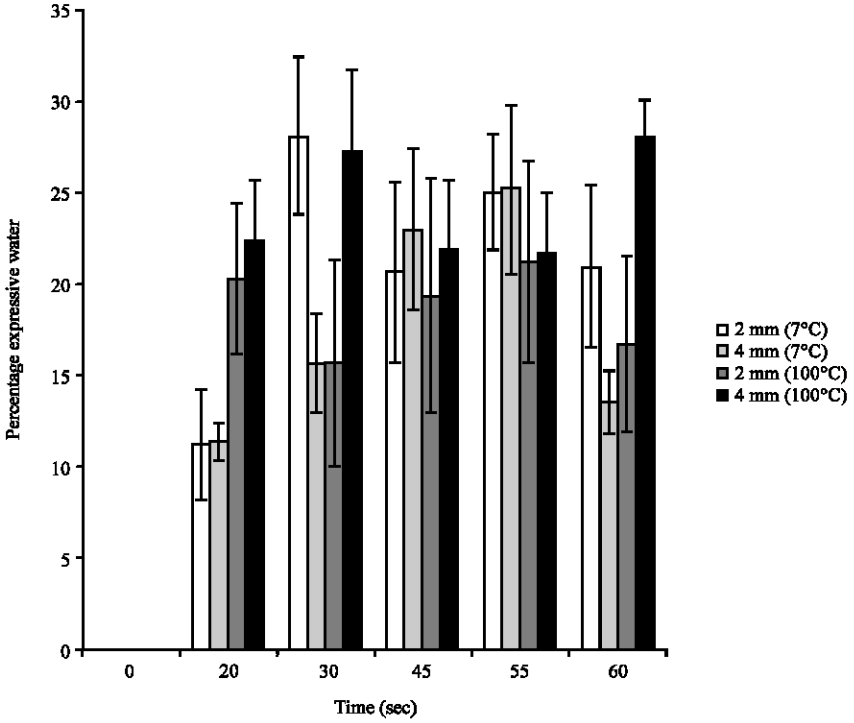

Fig. 1: Water holding capacity during blanching of the (a) yellow and (b) orange variety of *D. schimperiana*

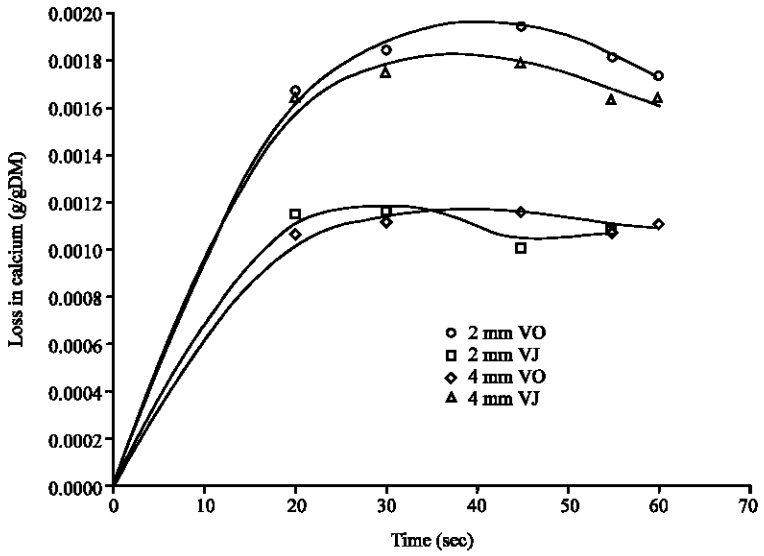

Fig. 2: Losses in calcium during blanching of the yellow and orange variety of *D. schimperiana*

of 4 mm thickness slices of the orange variety is significantly lower (0 to 0.0011 g g^{-1} DM) than 2 mm thickness slices of the same variety (0 to 0.00174 g g^{-1} DM). During blanching at 100°C, 2 mm thickness slices of the yellow variety lost significantly lesser calcium (0 to 0.0012 g g^{-1} DM) than 4 mm thickness slices of the same variety (0 to 0.0017 g g^{-1} DM).

Influence of blanching and drying on β-carotene and ascorbic acid contents of the orange variety yam

Water diffusivity during drying of blanched slices: Calculation of moisture diffusivity (m^2 sec^{-1}) (Table 1) of blanched and unblanched yams slices dried at 50°C shows that moisture diffusivity increase significantly with the increase in thickness. Water diffusion coefficients of blanched slices vary from 4.33×10^{-11} m^2 sec^{-1} for 2 mm thickness slices to 1.07×10^{-10} m^2 sec^{-1} for 4 mm thickness slices. For unblanched slices, it varies from 2.89×10^{-11} for 2 mm thickness slice to 5.56×10^{-11} m^2 sec^{-1} for 4 mm thickness slice. In general, water diffusion coefficients of blanched yam slices are significantly higher than unblanched yam slices.

Evolution of the β-carotene contents after blanching and drying: Losses in β-carotene (Fig. 3) after one minute of blanching at 100°C and during drying at 50°C of the orange variety of *D. schimperiana* was expressed as percentage (%). The data on dry basis was used to calculate the percentage of β-carotene losses as a function of time. The curves (Fig. 3) have been divided into two distinct phases: The first phase which shows important losses corresponds to the loss in β-carotene after one minute of blanching treatment and the second phase where the losses increase slowly corresponds to the continuous loss in β-carotene during the drying process. After 1 min

Table 1: Water diffusion coefficients during drying

	Water diffusivity (m^2 sec^{-1})			
	Blanched slices		Unbleached slices	
Thickness (mm)	Means	Standard deviation	Means	Standard deviation
2	4.33×10^{-11c}	4.87×10^{-12}	2.89×10^{-11f}	5.17×10^{-12}
3	7.86×10^{-11b}	5.51×10^{-12}	4.53×10^{-11e}	1.15×10^{-11}
4	1.07×10^{-10a}	4.90×10^{-12}	5.56×10^{-11c}	8.05×10^{-12}

a, b, c... Means followed by the same letter are not significantly different. LSD<0.05

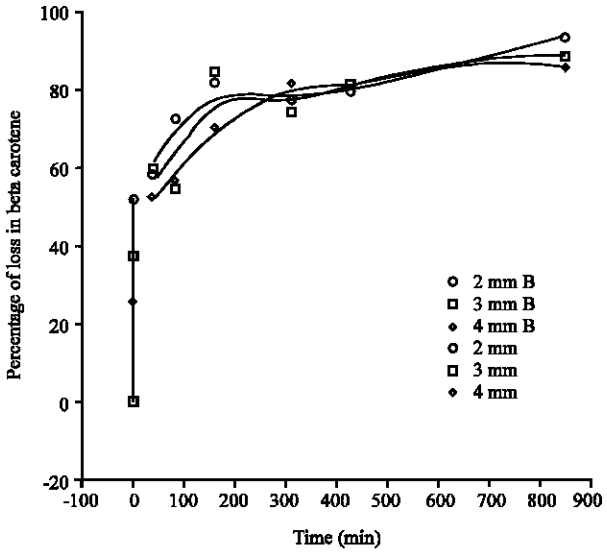

Fig. 3: Losses in β-carotene during blanching and drying at 50°C of the orange variety yam slices

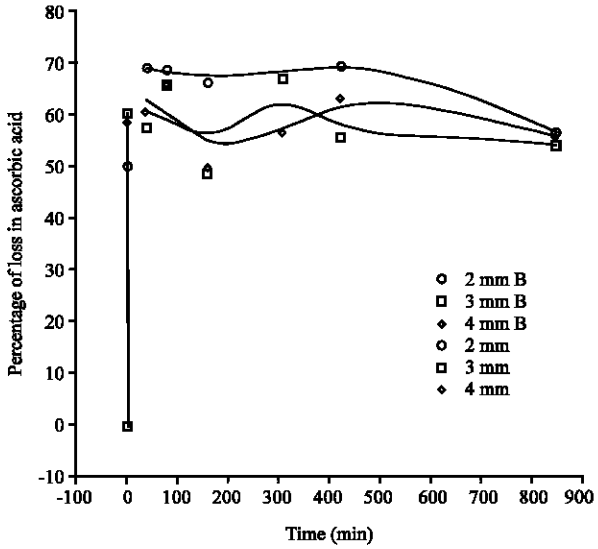

Fig. 4: Losses in ascorbic acid during blanching and drying at 50°C of the orange variety yam slices

of blanching at 100°C, 2 mm thickness slices (2 mm B) are those that lose more β-carotene (52%). They are followed by 3 mm (3 mm B) (37%) and 4 mm thickness slices (4 mm B) (26%). β-carotene (second phase) is also lost during drying with an average loss of about 89% at the end of the process. In general, 2 mm thickness slices loss more β-carotene (93.5%) than 3 mm (88.7%) and 4mm (85.5%) slice thickness at the end of the drying process.

Evolution of the ascorbic acid contents after blanching and drying: Losses in ascorbic acid (Fig. 4) after 1 min of blanching at 100°C and during drying at 50°C of the orange variety of *D. schimperiana* was also expressed as percentage (%). As in the case of β-carotene, the data on dry basis was used to calculate the percentage of ascorbic acid losses as a function of time. The curves (Fig. 4) have been divided into two distinct phases: The first phase which shows important losses corresponds to the loss in ascorbic acid after 1 min of blanching and the second phase where the losses seems to be constant corresponds to the continuous loss in ascorbic acid during the drying process. After 1 min of blanching, losses in ascorbic acid are lower in 2 mm slices thickness (2 mm B) (50%) than 3 mm (3 mm B) and 4 mm (4 mm B) slices thickness were the loss was about 60%. Ascorbic acid (second phase) was also lost during drying with an average loss of about 67% at the end of process. After one minute of blanching at 100°C, 2 mm slices thickness dried at 50°C lose more ascorbic acid (50 to 70%) during drying than 3 mm (60 to 68%) and 4 mm (59 to 64%) thickness slices.

DISCUSSION

The percentage of expressive water of 2 and 4 mm slices thickness of the orange and yellow variety blanching in 70°C increases significantly at the beginning of the process and decreases thereafter. This effect suggests that water absorption in the cells increases with blanching time. This behavior is normal since yams are rich in starch. Blanching at 70°C induce starch gelatinization. Gels trap water molecules and hydrophilic substances by forming weak energies links. As stated by Cheftel *et al.* (1983) this increase the proportion of water bound. The percentage of expressive water of 2 mm thickness slices of the orange variety and 4 mm thickness slices of the

yellow variety during blanching at 100°C evolves irregular. This marks dynamism in cellular exchanges according to blanching time. For 4 mm thickness slices of the orange variety and 2 mm thickness slices of the yellow variety, the percentage of expressive water increases significantly depending upon blanching time. High proportion of hot water absorbed by the slices remains in free state. This effect lets us think about a reduction of water absorption in the cells with blanching time. The reduction in the capacity of yam tuber to absorb water is often relying to modification in cell membrane structure (Treche and Delpeuch, 1979; Sealy *et al*., 1985; Afoakwa and Sefa-Dedeh, 2002). Indeed, yams are rich in starch. At high temperatures, two phenomena occur, starch gelatinization and modification in cell wall structure. The consequence is an obstruction of the pores and a reduction of the water absorption in the cells (Saguy *et al*., 2005). Whatever, the blanching temperature, the yellow variety slices have high percentage of expressive water. This effect lets us think about a very high sensitivity of this variety toward temperature. Cellular membranes are the places of the cellular exchanges. High temperatures may induce modification in cellular membranes structure and the consequence is a reduction of the cellular exchanges and a high expression of free water. For the orange variety slices, microstructural modifications of the cellular membrane are function of temperature. An increase in temperature was necessary to an improvement of cellular exchanges during blanching. Indeed, orange variety slices blanching at 100°C has percentages of expressive water significantly low. This suggests that as the temperature increase, water was more and more absorbed in the cells and the percentage of expressive water becomes low. This behavior is normal since blanching increases the proportion of water bound (Cheftel *et al*., 1983).

Calcium is loss during blanching. Losses are not uniform throughout the blanching period, with most losses occurring in the early stages. This behavior of calcium observed in the present study is comparable to the behavior describe by Henry and Massey (2001) concerning water soluble nutrients such as mineral salts. The intensity of calcium losses during blanching is dependent upon variety and slice thickness and seems to be relying to the dynamism of cellular exchanges. Loss in calcium during blanching of 4 mm thickness slices of the orange variety is significantly lower than 2 mm thickness slices of the same variety. Cellular exchanges during blanching of the orange variety at 100°C are especially high and the dynamism of the cellular exchanges is more important for 2 mm slices thickness of this variety. This could justify the higher losses in calcium of 2 mm slices thickness. During blanching at 100°C, 2 mm thickness slice of the yellow variety lost significantly lesser calcium than 4 mm thickness slices of the same variety. For this variety, cellular exchange during blanching of 2 mm thickness slices is much important than 4 mm thickness slices. A high proportion of hot water absorbs by the cells of 2 mm thickness slices remains therefore in free state. This justifies the high calcium losses of 4 mm thickness slices of the yellow variety. This variety being strongly sensitive to the temperature, cooking effects on the surface of the slices and/or the modifications in cellular membranes level was very important during blanching of small thickness slices. Those effects could probably slow down the movements of the calcium during blanching of 2 mm thickness slices.

Moisture diffusivity coefficient during drying of unblanched and blanched yam slices varies between 2.89×10^{-11} to 1.07×10^{-10} m^2 sec^{-1}. These values are lower than the values obtained by Falade *et al*. (2006) during drying of *D. alata* yam slices (9.92×10^{-8} to 1.02×10^{-7} m^2 sec^{-1}) and *D. rotundata* (0.829×10^{-6} to 1.298×10^{-5} m^2 sec^{-1}). But the values obtained lie within the range of 10^{-11} to 10^{-9} m^2 sec^{-1} for food material (Doymaz, 2006; Babalis and Belessiotis, 2004). In general, moisture diffusivity during drying at 50°C increases significantly with the increase in thickness. The more the thickness is greater, the more the diffusion coefficient is raised. This thickness

dependence of the moisture diffusivity was also observed by Sharma and Prasad, 2004 during microwave-convective drying of garlic cloves. In fact, this is an expect behavior since moisture migration become increasingly difficult for smaller thickness slices as the physical structure becomes denser and harder during drying. In general, water diffusion coefficients of blanched yam are significantly higher than unblanched yam. Indeed, studies of cellular exchanges during the blanching treatment showed that water holding capacity (% of expressive water) of the orange variety slices blanching at 100°C was low. A high proportion of hot water absorbs by the cells remains in bound state. Besides, high blanching temperatures reduce the cell wall resistance and increase the permeability of the cellular membrane to the movement of water. The Combination of these effects increases the water diffusivity and reduces the drying time. These observations concerning the movement of water during drying of blanched food were stated by Cheftel *et al.* (1983).

β-carotene and ascorbic acid are lost during blanching. Losses in **β**-carotene and ascorbic acid during blanching have been reported by many authors (Pinheiro-Santhana *et al.*, 1998; Cinar, 2004; Gebczynski, 2006; Rickman *et al.*, 2007). The intensity of losses in **β**-carotene and ascorbic acid during blanching is dependent upon variety and slices thickness and seems to be relying to the dynamism of cellular exchanges. As stated by Henry and Massey (2001), variety and thickness are one of the factors that affect nutrients loss during blanching in hot water. After one minute of blanching at 100°C, 2 mm thickness slices (2 mm B) lose more **β**-carotene and 4 mm thickness slices (4 mm B) less. On the contrary, in the case of ascorbic acid, losses are lower in 2 mm slices thickness (2 mm B) and higher in 4 mm slices thickness slices (4 mm B). Cellular exchanges during blanching of the orange variety at 100°C are very important. This justifies a high absorption of hot water in the cells. This phenomenon lead to a high **β**-carotene degradation as water is absorbed and the cellular membranes (where carotenoid are located) altered. The dynamism of the cellular exchanges of 2 mm thickness slices during blanching is more important. This could justify the high losses in **β**-carotene during blanching of these slices. Oxidative rather than thermal reactions could be the main reactions of ascorbic acid degradation during blanching. Indeed, the higher hot water absorption in the cells during blanching at 100°C may induce thermal degradation of oxidative enzymes. This phenomenon seems to be very important for small thickness slices as more reactive molecules are exposed to the heat and could justify the lower losses in ascorbic acid during blanching of 2 mm thickness slices.

β-carotene and ascorbic acid are also lost during drying. This observation is in conformity with results reported by many authors (Nicoleti *et al.*, 2004; Ozkan *et al.*, 2004; Oladele and Aborisade, 2009). In deed, **β**-carotene and ascorbic acid are nutrients that are highly degraded during drying because they are much more sensible to various mode of degradation. According to Rodriguez-Amaya (1997) and Rickman *et al.* (2007), **β**-carotene and ascorbic acid are lost during drying mainly by oxidization and isomerization. The influence of the thickness in **β**-carotene degradation during of blanched yam slices seems to be negligible. The apparent linearity of the curves of ascorbic acid degradation during drying shows that ascorbic acid is much stable during dehydration. This apparent stability confirms the benefic effect of blanching on the degradation of oxidative enzymes which seems to be responsible of vitamin C degradation. In general, after 1 min of blanching at 100°C, 2 mm thickness slices dried at 50°C loss more ascorbic acid and 4 mm slice thickness less. This effect let think about the predominance of thermal degradatives reactions during drying because blanching could have inactivated oxidative enzymes. Thermal degradation of ascorbic acid would be especially high as the reactive molecules are exposed to the heat. This could justify the higher losses in ascorbic acid during drying of 2 mm thickness yam slices.

A comparison of losses during blanching and subsequent air drying show that blanching treatment seems to be the limiting factor in β-carotene and ascorbic loss during blanching and subsequent air drying since more than 26 to 50% of the β-carotene and more than 50% of the ascorbic acid is loss during the blanching process depending upon slice thickness. This results are comparable to those obtain by Nursal Tosun and Yucecan (2007) during blanching of potatoes strips in hot water. Blanching parameters (Temperature and time of treatment), slices thickness and variety influenced cellular exchanges and losses in calcium, β-carotene and ascorbic acid during blanching. From present results, blanching protects β-carotene and ascorbic acid from degradation during subsequent air drying but nutrient losses during the blanching treatment is so high that an optimization of the blanching process before subsequent air drying is a necessity. Temperature and time of treatment, slices thickness and variety would be therefore parameters of choice for an optimization of the blanching process before subsequent air drying.

CONCLUSION

High intraspecific variability exists in cellular exchanges during blanching. During the process, there are losses in calcium, ascorbic acid and β-carotene. Temperature and time of blanching, slices thickness and variety are parameters that influence cellular exchanges and nutrients losses during blanching. They also influence the losses in β-carotene and ascorbic acid during the subsequent drying. Blanching at 100°C leads to higher losses in β-carotene and ascorbic acid and these losses continue during the subsequent drying. Slices thickness, temperature and time of blanching could be therefore parameters of choice for an optimization of the blanching and drying process.

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