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EFFECT OF PRE-TREATMENT ON SOME PHYSICAL-CHEMICAL PROPERTIES OF DRIED CARROTS

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Abstract

Carrot is the most commonly used vegetable for human nutrition and is an excellent source of β-carotene, vitamin A and potassium, and contains cholesterol-lowering pectin, vitamin C, vitamin B6, thiamine, folic acid, and magnesium. Carrots are highly seasonal and abundantly available at particular times of the year. For extending the availability of this root, several preservation processes can be used, but convective drying is one of the most important since it not only extends vegetable shelf life significantly but also diversifies the offer of foods for consumers. However, convective drying can also give rise to significant chemical changes (non-enzymatic browning, among others), which may affect the quality of the product. Pre-drying treatments of solid food products can be used as a way to augment product quality and to modify the structure of food products so as to improve mass transfer coefficients in drying. In this context, assessments of the physical and chemical properties were made in order to investigate the effects of sodium metabisulphite at different concentration/time combinations prior convective drying of carrots.

The carrots used in this study were purchased in a local market, and hand peeled and cut into slices with thickness of 10 mm. Before convective drying at 60 ^{0}C the slices of carrots were submitted to pre-treatments as follows: a) dipping in a water solution of 0.25% of sodium metabisulphite for 60 and 90 min. and 1% of sodium metabisulphite for the same times, at room temperature; b) dipping in an equal mass of plain water for 60 and 90 min. at room temperature (as control sample). Some chemical properties of the fresh and dried samples were evaluated with classical methods, namely moisture content, fiber, ashes and sugars (reducing, total and non-reducing sugars). The physical properties evaluated were color and texture. Color was evaluated with a Colorimeter in the CieLab color space and texture was measured Color was evaluated with a Colorimeter in the CieLab color space and texture was measured by texture profile analysis with a texturometer.

The main results show that the different combinations concentration/time of sodium metabishulphite dipping has a similar effect on the chemical properties of the dried carrots. Furthermore, the dried slices of carrots with and without pre-treatment originated products with similar nutritional characteristics. With respect of color, the total difference of color and browning index was similar to the different solutions of sodium metabishulphite. In addition the browning of the dried carrots was, apparently, independent of the pre-treatment. Similarly, the different combinations of pre-treatment had no visible effect on textural parameters and generally the hardness decreased with the pre-treatments.

From the obtained results it was concluded that the different concentration/time combinations of sodium metabisulphite solutions had no visible improvement on the quality of the dried carrots.

***Key words**: Carrots, Pre-treatment, Drying, Color, Texture.*

1. Introduction

Carrot is one of the most commonly used vegetables for human nutrition. These vegetables are an excellent source of β-Carotene reported to prevent cancer. In fact, the carrots present the highest carotenoids content among food products (Magdalena and Markowski [1]). Carrots also possess vitamin A and potassium, and contain cholesterol-lowering pectin, vitamin C, vitamin B_6, thiamine, folic acid, and magnesium (Desobry, *et al*. [2]). Thus, carrots provide health benefits including strong antiseptic qualities, which can be used as a laxative, poultice and for the treatment of liver conditions (Erenturk and Erenturk [3]).

Carrots are highly seasonal and abundantly available at particular times of the year. For extending the availability of this root, several preservation processes can be used and the drying is one of the most important, since it not only significantly extends vegetable shelf life but also diversifies the offer of foods for consumers (Lewick [4]). Behind the dehydration technique, the hot air drying under forced convection is the most common given that it offers the advantages of low complexity and cost (Garcia-Noguera, *et al*. [5]).

Dried, juice, and powder forms of carrots have been used in commercial use, such as in dehydrated soups and in the form of powder in pastries and sauces.

Several studies have been performed on the drying of carrots. For instance, modelling the process with different drying techniques was one of the most important aspects studied (Erenturk and Erenturk [3]; Prakasha *et al*. [6] 2004; Cui Xu and Sun [7]; Doymaz [8]). However, convective drying can also give rise to significant chemical changes (non-enzymatic browning, among others), which may affect the quality of the product.

The formation of dark-coloured pigments in foods during processing and storage is a very common phenomenon. The mechanism of browning may be the Maillard reaction, the result of ascorbic acid-mediated process of caramelization. However, most of the browning occurring in foods during drying is through the Maillard reaction (Negi and Roy [9]).

Several authors have suggested the pre-drying treatment of solid food products, either physically or chemically, as a means to both improve product quality and to modify the structure of food products so that the mass transfer coefficients in drying can be optimized. The main purpose of pre-treatment is generally to inactivate enzymes like polyphenoloxidase, peroxidase and phenolase, and to inhibit some undesirable chemical reactions, such as Maillard reaction and caramelization, which cause many adverse changes in the product. These pre-treatments include blanching, osmotic dewatering, sulfiting and immersing in such diverse solutions as calcium chloride, ascorbic acid, citric acid, and gelatinised starch (Lewicki [3]). In addition, other methodologies such as high-intensity ultrasound have emerged as an alternative to pre-treatment.

Inorganic compounds are quite often used to modify properties of the plant tissue subjected to drying. Negi and Roy [9] reported that sulphite treatment retarded carotenoid breakdown, inhibited lipid oxidation and decreased discoloration of dehydrated carrots. Bernás *et al*. [10] identified a sodium metabisulphite as a typical preliminary step for processing mushrooms since it retards browning reactions and prevents colour degradation during drying and storage. The objective of this work was to study the effects of chemical pre-drying treatment (sodium metabisulphite) at different concentration/time combinations on chemical composition, colour, and texture of dried carrots.

2. Materials and Methods

2.1 Samples

The carrots used in this study were purchased in a local market, and then hand peeled and cut into slices with thickness of 1cm and diameter of 3cm.

2.2 Pre-treatments before dehydration process

The carrot slices were treated as follows: a) dipped in a water solution of 0.25% of sodium metabisulphite for 60 and 90 minutes and 1% of sodium metabisulphite for the same times, at room temperature; b) dipped in an equal mass of plain water for 60 and 90 minutes at room temperature (as control sample). After each pre-treatment, the excess of water on sample surface was superficially removed with paper towel.

2.3 Drying experiments

Drying experiments of untreated and treated carrots were carried out in a convection oven at 60 ^{0}C, with an air speed of 0.2 m/s, in order to reduce the average moisture of carrots to about 15% (w/w). The drying time of the samples was 8 hours.

2.4 Chemical and physical analysis

The evaluated chemical properties on fresh and dried samples were moisture content, fibre, ashes, and sugars (reducing, total, and non reducing sugars), using the Official Methods of Analysis of AOAC (Association of Official Analytical Chemists). Except for the moisture content, which was expressed in fresh weight, all other results were expressed in terms of dry matter, in order to allow a direct comparison of values for the different dried samples.

The studied physical properties were colour and texture. The colour of the fresh and dried samples was assessed using a handheld tristimulus colorimeter (Chroma Meter-CR400, Konica Monolta). The total colour change was the parameter considered for the overall colour difference evaluation, between a dried sample and the fresh vegetable. The colour coordinates obtained from fresh samples were taken as a reference in order to assess the extent of colour change and a larger total colour difference denotes greater colour change from the reference material.

The texture profile analysis (TPA) for all samples was made by a texturometer (TA.XT.Plus from Stable Micro Systems). The texture profile analysis was carried out by two compression cycles between parallel plates performed via a flat 75 mm diameter plunger, with a 5 second period of time between cycles. TPAs were performed in 20 samples for each state and the textural properties measured were hardness, springiness, and cohesiveness.

3. Results and Discussion

Convective drying of carrots was carried out at 60 ^{0}C to compare the influence of chemical pre-treatments with sodium metabisulphite for two concentration/time combinations on the chemical composition of the dried carrots. Table 1 presents the mean values for moisture content, ash, protein, crude fibre, total sugars, and reducing sugars after the drying of the carrots. The results reveal that the pulp of fresh carrots has appreciable ash, protein, and sugars contents.

The chemical composition of the dried carrots without pre-treatment and treated with sodium metabisulphite is illustrated in Table 2, and the results highlight that the drying processes permits keeping the nutritional characteristics of dried carrots as they were in the fresh state. However, it is important to notice that the reducing sugars diminished with drying. The reduction of the sugars in the dried carrots, probably due to enzymatic and non-enzymatic browning, was 50%.

The mean value of moisture content of carrots subjected to treatments prior to drying reveals that, in general, the sulfiting process hinders drying in the range of 0.25% and 1% of sodium metabisulphite and treatment time of 60 and 90 minutes. The control samples increased the effective water diffusivity of carrot during air-drying process as compared with untreated and treated samples.

The pre-treatments allow similar values of ash, protein, crude fibre, and total sugars, when compared with those of the untreated sample, independently of the concentration/time combination.

3.1. Influence of pre-drying treatment on colour

The fresh carrots exhibited a light yellow colour, with L (brightness), a* (redness) and b* (yellowness) colour parameters equal to 53.74, 27.59 and 49.20, respectively. Alegria *et al*. [11] present CIElab coordinates of 60.8, 23.1, and 60.6 to raw fresh carrots.

The average values of the colour parameters for dried untreated and treated carrots are presented in Table 3 for L, a*, and b* colour coordinates.

The drying of untreated dried carrots allows an increase of the L and a* coordinates and a decrease of the b* parameter. In particular, the greenness parameter (a*) increased 17%, hence indicating that the samples dried at 60 ^{0}C presented a lesser intensity of the green colour than the fresh product (increase of a* value signifies a deeper red chrome indicating browning reactions). Thus, the dried untreated carrots turned the final product lighter and less green (pale yellow colour).

Table 1. Chemical composition of the fresh carrots

Moisture (g/100 g)	Ash (g/100 g d.b.)	Protein (g/100 g d.b.)	Crude fibre (g/100 g d.b.)	Total sugars (g/100 g d.b.)	Reducing sugars (g/100 g d.b.)
87.02 ± 0.14	6.87 ± 0.44	8.12 ± 0.14	3.07 ± 0.98	85.01 ± 0.57	18.58 ± 0.67

Values expressed are means of 3 replicas ± standard deviation.

Table 2. Effect of sodium metabisulphite treatment on nutritional characteristics of dehydrated carrot slices

Pre-treatment	Moisture (g/100 g)	Ash (g/100 g d.b.)	Protein (g/100 g d.b.)	Crude fibre (g/100 g d.b.)	Total sugars (g/100 g d.b.)	Reducing sugars (g/100 g d.b.)
Untreated	16.47 ± 0,63	7.27 ± 1,92	7.66 ± 0,03	5.67 ± 0,52	85.29 ± 1,88	9.25 ± 0,16
SMB - 0.25%/60 min.	24.86 ± 1.73	7.78 ± 0.19	5.97 ± 0.47	5.50 ± 0.75	86.18 ± 0.65	6.87 ± 0.13
SMB - 0.25%/90 min.	17.66 ± 2.06	7.96 ± 0.35	6.33 ± 0.65	5.69 ± 0.85	85.74 ± 0.44	10.12 ± 0.11
SMB - 1%/60 min	14.46 ± 1.42	6.28 ± 1.13	5.84 ± 0.49	6.02 ± 0.71	87.64 ± 1.02	9.51 ± 0.11
SMB - 1%/90 min	20.06 ± 1.62	6.32 ± 0.79	5.95 ± 0.91	4.50 ± 0.82	87.68 ± 0.94	11.15 ± 0.14
Control 60 min.	11.91 ± 0.44	4.94 ± 0.15	4.36 ± 0.11	6.96 ± 0.89	90.33 ± 0.23	10.27 ± 0.05
Control 90 min.	11.13 ± 0.45	4.70 ± 0.09	4.52 ± 0.10	6.60 ± 0.51	90.41 ± 0.17	9.03 ± 0.35

SMB- sodium metabisulphite

Values expressed are means of 3 replicas ± standard deviation.

Table 3. Colour coordinates to untreated dried carrots and subjected to pre-treatment with sodium metabisulphite

Pre-treatment	L	a*	b*
Untreated	60,26 ± 2,25	32,54 ± 1,81	45,97 ± 4,00
SMB - 0.25%/ 60 min.	60,80 ± 1,67	31,49 ± 3,05	39,03 ± 3,50
SMB - 0.25%/ 90 min.	62,05 ± 3,33	30,89 ± 3,00	39,02 ± 3,50
SMB - 1%/ 60 min.	58,26 ± 2,40	31,77 ± 3,95	39,31 ± 3,32
SMB - 1%/ 90 min.	59,78 ± 2,44	30,55 ± 3,13	38,66 ± 2,28
Control 60 min.	64,14 ± 4,15	24,86 ± 2,87	40,60 ± 1,70
Control 90 min.	64,69 ± 2,24	24,95 ± 1,76	41,07 ± 1,83

The carrot samples subjected to treatments of 0.25% and 1% of sodium metabisulphite at 60 and 90 minutes do not reveal a noticeable loss of brightness neither redness parameters (a*). The mean L and a* values for the chemical treatments at different concentration and time were statistically identical. Nevertheless, a similar decrease of 15% was observed to de b* coordinate in the four pre-treatments samples as compared with untreated samples. Furthermore, for both concentrations of sodium metabissulfite the increase of treatment time had a reduced effect on the coulor parameters.

The total colour change (Figure 1) of untreated dried carrots was 10 and this value increased to around 14 for the four chemical treatments (values of the chemical-treated samples were statistically identical ($p>0.05$)). This implies that the chemical pre-treatments did not influence positively the colour of carrots during drying, which contradicts the result obtained by Krokida *et al*. [12] for sulphite pre-treated materials such as apple, banana, and potato, though being in accordance with the Argyropoulos *et al*. [13] findings on chemical treatment of dried mushrooms.

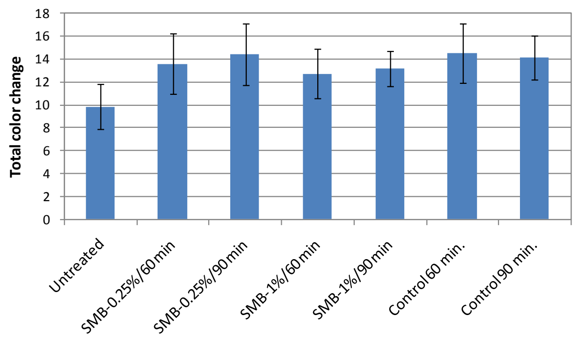

Figure 1. Total colour change of untreated dried carrots and pre-treated with sodium metabisulphite

3.2. Influence of pre-drying treatment on texture

Figure 2 shows the results of the hardness determined by a compression test performed via a texturometer. Hardness is a textural attribute that is also very important for determining product acceptability. Convective air drying might have caused physical and structural modifications of the carrots tissue. The hardness of the fresh carrots was 273 N. The results show that, with respect to hardness, the drying softened the carrots in all cases.

Concerning the pre-drying treatments, it was observed that at a concentration of 0.25% of metabisulphite the hardness of the carrots exhibited lower values than those of the untreated vegetables, thus originating an undesired level of softening of carrots, probably due to a decreased cell adhesion. At this concentration, the increase of treatment time from 60 to 90 minutes had no noticeable effect on hardness. However, as the concentration of sodium metabisulphite increased to 1% this pre-drying treatment exhibited higher values of hardness than the ones for both untreated carrots and pre-dried treated with 0.25% of metabisulphite solution. In fact, the increase of time treatment from 60 to 90 minutes had doubled the hardness of the dried product.

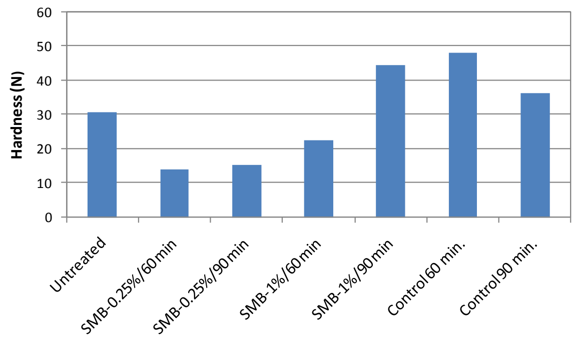

Figure 2. Hardness of untreated dried carrots and pre-treated with sodium metabisulphite

The springiness of fresh carrots was 85.5% and this value decreased to 73.0% in the case of untreated dried carrots (Figure 3). The springiness of treated samples was approximately 80% independently of the concentration of sodium metabisulphite/time combination.

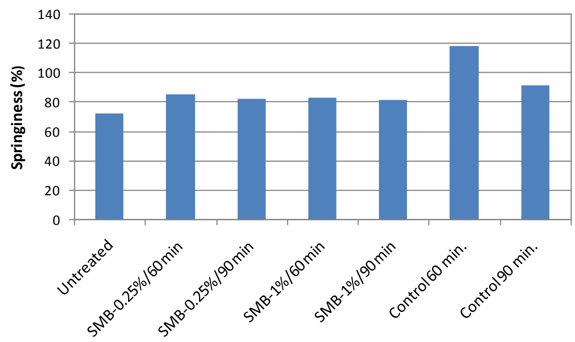

Figure 3. Springiness of untreated dried carrots and pre-treated with sodium metabisulphite

Figure 4 highlights the effect of drying on cohesiveness, which is related to the strength of the internal bonds of the sample. This parameter revealed a value of 0.9 for fresh carrots. The drying process decreased cohesiveness slightly and the pre-treatment had no significant effect on this texture parameter.

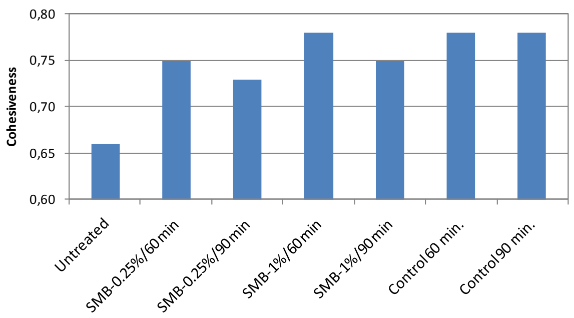

Figure 4. Cohesiveness of untreated dried carrots and pre-treated with sodium metabisulphite

4. Conclusions

- The results show that during convective drying of carrots, lightness and redness increased slightly while yellowness decreased in the case of untreated and pre-treated samples. In addition, the use of pre-treatment with metabisulphite at different concentration/time combinations did not influence positively the colour of carrots during drying.

- The pre-drying treatment of carrots had a slight effect on the texture attributes of the dried product since the hardness was only increased for the pre-treatment method with a concentration and time combination of 1% and 90 minutes. However, the textural properties changed when compared to the fresh product, as expected.

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