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EFFECT OF CHEMICAL TREATMENTS ON THE STABILITY OF DEHYDRATED CARROT*

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To improve the quality of dehydrated carrot, fresh carrot was treated with several chemicals prior to dehydration. The effectiveness of the chemicals was evaluated by following changes in carotenoid content, lipid oxidation, non-enzymic browning (NEB) and rehydration capacity of carrots after dehydration, and during 180 days of storage in air at 37° in sealed tinplate cans. Treatment with antioxidants, chelating agents and surface coating materials had little effect on the stability of dehydrated carrot. Ammonium bicarbonate, sodium tripolyphosphate and EDTA treatments enhanced discolouration, whereas treatment with calcium chloride adversely affected the rehydration capacity of dehydrated carrot. Treatment, with sodium tetraborate significantly improved the rehydration capacity, whereas sodium metabisulphite treatment retarded carotenoid breakdown and lipid oxidation, and inhibited changes causing discolouration and toughening of carrot tissue.

INTRODUCTION

Although several studies of the effect of chemical treatment on the quality of dehydrated foods including carrot have been reported by many workers [1-7], information regarding their effect on the storage stability of foods is limited. Moreover, in almost all reported studies, a particular chemical has usually been examined for one particlular effect regardless of the effect on several other equally important quality parameters. Since food is a complex system, several inter-related chemical and physico-chemical deteriorative changes leading to destruction of plant pigments, formation of brown colour and those affecting flavour and texture occur concurrently in deteriorating dehydrated vegetables. Moreover, some chemicals, though effective against a particular deteriorative change, may even promote several other undesirable changes. Consequently, a series of comparative studies using a variety of treatments was undertaken to collect sufficient information regarding the effects of such treatments on the overall stability of dehydrated carrots during storage.

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MATERIAL AND METHODS

All the chemicals listed in Table 1 were applied as a single treatment. In most cases only one concentration of the chemicals, namely the maximum amount allowed in food under Australian regulations, was studied. Adequate mixing of carrot dice used for each set of treatments was made to ensure complete uniformity of samples. To be able to compare all treatments a water-dip treatment was carried out with each set of chemical treatments to serve as a reference. The seven reference treatments thus conducted received no additional treatment other than steam blanching followed by a distilled water dip, and then drying under conditions similar to those for the chemically treated samples. Additionally a control treatment with sodium metabisulphite was conducted to compare the extent of deterioration in quality of dehydrated treated carrot.

Blanched carrot dice (1.8 kg) were immersed for 6 min in 2l of each of the chemical solutions in a stainless steel bowl. Water soluble or partially water insoluble chemicals such as starch, pectin, gum arabic and NDGA were homogenously suspended in water at room temperature by blending with an ultraturrax disintegrator and the carrots immediately dipped in the chemical suspension. The pH of the

chemical solutions or suspensions was adjusted to 6.2, the pH of fresh carrot tissue, with HCl or NaOH prior to dipping of blanched carrot. The treated carrots were drained for 10 min, loaded on to stainless steel wire mesh trays (7.4 kg/m^2), and dehydrated at dry and wet bulb temperatures of 71° and 38° respectively to a moisture content of 3.5–4.2% (Table 1). The dehydrated carrot dice were mixed thoroughly and uniform samples (60 g) were hermetically sealed under vacuum into tinplate cans (74 x 112.5 mm) and incubated at 37°. Sulphited carrots used as a control were stored in nitrogen at -12°. Samples were removed after 30,90 and 180 days of storage, ground to pass a 20 mesh sieve and analysed for carotenoid content, lipid oxidation and NEB. Rehydration properties were measured on diced carrot before grinding.

The source of carrot, the procedure for blanching of diced carrot, and the methods used for the determination of moisture content, carotenoid content, lipid oxidation and rehydration properties have been reported in previous publications [8–10]. NEB was measured by a modification of the method of Simon *et al.* [4] in which dehydrated carrot was extracted with 2% acetic acid, mixed with equal volumes of ethanol, and centrifuged. The absorbance of the supernatant was measured at 420 nm on a Unicam SP 600 spectrophotometer. The absorbance values reported in Table 6 were calculated by subtracting the absorbance of extracts of treated carrots after dehydration from the respective values obtained for samples stored for various periods at 37°.

RESULTS AND DISCUSSION

The chemicals studied (Table 1) either have been applied to foods previously or have been approved for use by the Australian National Health and Medical Research Council, or were of academic interest. The treatments included in these studies were the antioxidants, nordihydroguaiaretic acid (NDGA) and sodium tripolyphosphate ($Na_5P_3O_{10}$) to control lipid oxidation and carotenoid destruction; metal chelating agents, EDTA sodium salt and sodium tripolyphosphate for protection of carotenoid pigments against metal oxidation; NEB retardants, calcium chloride, sodium tetraborate and sodium metabisulphite; surface coating agents, starch, pectin, gum arabic for preventing oxygen access to the tissues; chemicals for texture improvement, sodium chloride, sodium tetraborate and glycerol; and for partial replacement of oxygen from tissues by ammonia with ammonium bicarbonate to minimise carotenoid destruction. Instead of fat soluble antioxidants such as BHA and BHT, which are usually added to lipids to control lipid oxidation, NDGA was chosen since it is more soluble in lipid aqueous systems.

Carotenoid Destruction. In order to determine the effect of the natural variation in pigment content on the stability of carotenoids, the results obtained from the reference treatments, can be examined (Table 2). Although a large variation in pigment content was found in the reference samples, such a variation had no significant effect on rates of pigment breakdown. The results agree with the findings of Stocking and Weier [12] but differ from those of Weier and Stocking [13], both these latter studies being on ground dehydrated carrots. From these studies it can be concluded that the level of corotenoid pigments present in carrot used in this investigation apparently had no effect on subsequent changes during storage. Thus any effect noticed in stability of carotenoids in dehydrated carrots treated with chemicals can be considered primarily due to the chemical treatment applied.

From a practical viewpoint, any suitable chemical treatment must protect pigments to an extent which is greater than the best protection afforded by the water dip treatment alone. During the first month of storage at 37°, only treatments with $Na_2S_2O_5$, NH_4HCO_3, $Na_5P_3O_{10}$ and $Na_2B_4O_7$ showed carotenoid losses lower than the water dip treatment (Tables 2 and 3). None of the chemical treatments studied were found to give carotenoid losses greater than the water dip treatment. A similar situation prevailed during the next 2 months of storage. Noticeable protection of carotenoids resulted only from treatment by $Na_2S_2O_5$, NH_4HCO_3 and $Na_5P_3O_{10}$, which gave about 2.3, 1.9 and 1.5 times greater carotenoid retention, respectively, than the water dip treatment alone.On further storage, the situation became rather more complicated. Many chemical treatments which were not as effective previously, showed carotenoid losses lower than that for water dipping. The cause of the apparent pigment protection at this stage is not known, but was probably not due to the chemical treatments alone. The complexity of the reactions at the latter stages of storage suggests the depletion of oxygen and formation of certain substances which prevent, delay or do not continue to promote the oxidation of carotenoids in stored dehydrated carrots. However, the quality of the dehydrated treated carrots at this stage of storage was poor in any case and decreased pigment loss was of little value. Nevertheless, the additional protection shown by those treatments which had already reduced carotenoid breakdown were considered to be of some value.

To further characterise the effect of different chemical treatments, storage life was calculated. Since off-flavour

Table 1. Concentration of chemicals used and moisture content of subsequent dehydrated treated carrot.

Chemical	Concentration (% W/V)	Moisture content (%)
Nordihydroguaiaretic acid (NDGA)	0.03	3.8
Ethylenediamine tetraacetic acid (EDTA)	0.03	3.7
Calcium chloride ($CaCl_2$)	0.5	3.8
Sodium tripolyphosphate ($Na_5P_3O_{10}$)	0.5	4.1
Sodium tetraborate ($Na_2B_4O_7$)	0.5	3.0
Sodium chloride (NaCl)	0.5	3.6
Ammonium bicarbonate (NH_4HCO_3)	0.1,1.0	4.0
Sodium metabisulphite ($Na_2S_2O_5$)	0.6	4.2
Glycerol	1.0	3.5
Starch	2.5	3.9
Pectin	0.3	3.7
Gum arabic	2.5	3.5
Water dip[a]	Distilled water	3.8
Control[b]	0.6	3.8

a Mean of 7 samples. b Sulphited, stored in nitrogen at – 12°.

Table 2. Loss of carotenoids in dehydrated carrots previously blanched, then dipped in distilled water prior to dehydration.

Initial carotenoid content (μg/g, moisture free basis)	Carotenoid loss (%) Storage time at 37° (days)		
	30	90	180
1400	21.0	42.7	61.1
1370	24.5	49.5	63.5
1320	17.5	42.8	61.5
1291	19.0	43.9	62.0
1220	18.8	44.2	61.3
940	16.2	40.0	59.0
792	22.5	46.0	62.0
Mean	19.9	42.2	61.5

develops as a result of carotenoid destruction, Tomkins *et al.* [14] reported that dehydrated carrots were no longer acceptable when carotenoid loss exceeded about 20 %. On this basis carrot treated with various chemicals prior to dehydration showed marked variation in storage life (Table 4). A minimum shelf life of only 25 days at 37° was found for carrot treated with NaCl whereas a storage life 4 times greater was observed for the sample treated with $Na_2S_2O_5$. A storage life of 71 to 74 days for samples treated with NH_4HCO_3, and of 54 days for samples treated with $Na_5P_3O_{10}$, were also significantly greater than that for carrot treated with NaCl or with water alone. However, the storage life 28 – 39 days for the remaining chemically treated samples was found to lie in the range of 22 – 39 days for reference samples given only a water dip treatment, showing that these treatments had no additional effect on carotenoid stability.

From these studies it is obvious that chemicals as pectin, gum arabic and starch applied to produce a surface coating on the carrot pieces to limit access of oxygen to the carotenoids did not protect carotenoid pigments. Pectin has also been shown in other studies to be ineffective in protecting carotenoids of dehydrated carrot dice [2] and of sweet potato flakes [6]. It can be concluded that pectin

Table 3. The effect of chemical treatments on the loss of carotenoids of dehydrated carrot during storage at 37°.

Chemical treatment	Carotenoid loss (%) Storage time at 37° (days)		
	30	90	180
NDGA	17.5	37.4	51.3
EDTA	16.6	36.9	48.5
$CaCl_2$	16.5	45.0	62.4
$Na_5P_3O_{10}$	11.0	30.0	39.5
$Na_2B_4O_7$	12.9	39.9	57.3
NaCl	22.3	50.5	58.2
NH_4HCO_3 (0.1%)	10.5	23.5	36.5
NH_4HCO_3 (1.0%)	9.5	23.0	35.8
$Na_2S_2O_5$	9.4	19.1	24.8
Glycerol	16.7	39.0	51.0
Starch	17.4	39.5	52.7
Pectin	21.6	49.0	59.9
Gum arabic	17.4	42.1	57.2
Control[a]	1.5	2.5	2.9

a. Sulphited, stored in nitrogen at – 12°.

Table 4. Effect of chemical treatments on the storage life, as determined by carotenoid loss, of dehydrated carrot stored at 37°.

Chemical treatment	Storage life (days for 20 % loss in carotenoid pigments)
NDGA	35
EDTA	38
$CaCl_2$	35
$Na_5P_3O_{10}$	54
$Na_2B_4O_7$	39
NaCl	25
NH_4HCO_3 (0.1%)	71
NH_4HCO_3 (1.0%)	74
$Na_2S_2O_5$	100
Glycerol	36
Starch	38
Pectin	28
Gum arabic	35
Water dip[a]	
range	22-39
mean	30

a. Seven samples.

and particularly gum arabic, which produces cracks in the coating on drying, are not suitable materials to be used for surface coating of diced carrot which is sensitive to oxidation. The results of starch treatment differ from those of Tomkins *et al.* [14], Masure *et al.* [3], and Kuppuswamy and McBean [15] for dehydrated carrots, but as the method of application of the starch in the present work differed from that in the reported studies, the results of the various trials cannot be compared directly.

Carotenoid destruction was little affected by chelating agents such as EDTA and $Na_2B_4O_7$, whereas it was noticeably reduced by $Na_5P_3O_{10}$ treatment which has also been reported to be an effective antioxidant in sweet potato flakes [14]. Since EDTA produced discolouration in dehydrated carrot, it is assumed that ineffectiveness of EDTA partially resulted from its reaction with constituents other than metals present in dehydrated carrot stored at elevated temperature.

The antioxidant NDGA had little effect on carotenoid stability in dehydrated diced carrot. Similar observations on dehydrated carrot have also been reported by other workers [1,13]. However NDGA has been shown to be considerably effective when used in model systems [1,16]. The ineffectiveness of NDGA, as well as other fat soluble antioxidants reported in the literature [1,13] in preventing carotenoid loss in dehydrated carrots is presumably due to the failure of the antioxidant to reach the carotenoids in the chromoplasts of the tissue, although NDGA is more soluble in lipid-aqueous systems than other fat soluble

antioxidants (BHT, BHA), or to the fact that NDGA does not inhibit the reaction(s) leading to carotenoid breakdown. Because of the low solubility of NDGA in water, the former reason seems to be more acceptable.

The most effective treatment preventing carotenoid oxidation in these studies was that involving $Na_2S_2O_5$. However, varied effects of this treatment on carotenoid stability have been reported. Increased carotenoid stability of carrot has been reported by Cruess [17] and Weier [18], but little effect of $Na_2S_2O_5$ treatment on this quality parameter has been reported by many other workers, for dehydrated diced carrots [2,3, 10, 13].

Since carotenoid oxidation in dehydrated carrot was not affected by treatment with EDTA, it can be concluded that carotenoid oxidation in this system is not catalysed only by metals present in the tissue in the form of ions or protein complexes. On the other hand, a significant reduction in carotenoid oxidation observed in dehydrated carrot treated with $Na_2S_2O_5$, a well-known reducing agent which can additionally complex with organic peroxides [20], suggests oxygen to be the main factor responsible for carotenoid oxidation. These finding were further substantiated by a significant reduction in carotenoid oxidation in carrot treated with NH_4HCO_3 which, being highly soluble in cold water, can diffuse deep into the tissue replacing oxygen, already present in the tissue, with NH_3 produced from NH_4HCO_3 on heating during dehydration, and thus hindering further diffusion of oxygen from outside the tissue. However, NH_4HCO_3 has other adverse effects producing brown carrot.

Although SO_2 is a powerful reducing agent and reduces the oxygen content in the pack [21], it reacts irreversibly with food constituents to a considerable extent [21,23]. Thus high concentrations of SO_2 are required to inhibit carotenoid oxidation in dehydrated foods such as carrot, and its effectiveness is determined by the prevailing storage conditions. Higher concentrations of SO_2 not only impair the nutritive value of foods [24-26], but are also possibly harmful to the consumer [27-29]. Thus efforts should also be focussed to gain information about its reactions with foods and moreover to reduce its level in foods to a minimum. Maximum levels of SO_2 permitted legally in various countries have been published for various food products including dehydrated carrot, in which the permitted concentration ranges from 500 to 2000 mg/kg [30].

Lipid Oxidation. Regardless of the chemical treatment applied, lipid oxidation increased during storage (Table 5). The rate of oxidation during the initial stages of storage

Table 5. Effect of chemical treatments on lipid oxidation of dehydrated carrot stored at 37°.

Chemical treatment	TBA number (mg malonaldehyde/kg sample)			
		Storage time (days)		
		30	90	180
NDGA	0.52	0.65	0.84	1.35
EDTA	0.55	0.69	0.88	1.07
$CaCl_2$	0.32	0.55	0.94	1.05
$Na_5P_3O_{10}$	0.33	0.50	0.83	0.84
$Na_2B_4O_7$	0.54	0.79	1.20	1.56
NaCl	0.58	0.79	1.17	1.32
NH_4HCO_3 (0.1%)	0.80	0.86	0.98	0.83
NH_4HCO_3 (1.0%)	1.21	1.32	1.57	1.39
$Na_2S_2O_5$	0.77	0.90	1.07	1.10
Glycerol	0.64	0.72	0.92	1.17
Starch	0.51	0.68	0.75	1.23
Pectin	0.43	0.66	1.06	1.38
Gum arabic	0.43	0.62	1.17	1.13
Water dip[a]				
range	0.48–0.81	0.62–0.97	0.90–1.27	1.10–1.32
mean	0.58	0.76	1.24	1.28
Control[b]	0.51	0.61	0.62	0.83

a. Seven samples; b. Sulphited, stored in nitrogen at – 12°.

was rapid, but decreased as storage progressed, to the extent that the TBA number of the samples treated with NH_4HCO_3 after 180 days of storage at 37° was low compared to the value obtained after 90 days of storage. Similar observations have been reported by Aray *et al* [31], on dehydrated minced mutton and pre-cooked dehydrated rice. A decrease in the rate of lipid oxidation towards the end of storage suggests either depletion of oxygen in the sealed cans, increased production of products of lipid oxidation. On the other hand, a net decrease in TBA number during storage suggests interaction of malonaldehyde with other components in the sample.

A maximum TBA value of 1.2 mg MA/kg sample was found after dehydration for carrots treated with NH_4HCO_3 and the TBA value remained highest during 180 days of storage at 37°. However, the TBA values of all chemically treated, reference and control samples after dehydration and storage at 37° for 180 days are low (Table 5) compared to those of oxidised animal products where TBA values may reach 300 or more. Hence, it would appear that carotenoids in dehydrated treated carrots inhibited lipid oxidation, and the chemicals used had little effect on lipid oxidation of the carrot samples. Lime [32], in model system studies on lipid oxidation of β-carotene and fatty acid esters, observed that peroxide values remained low until the β-carotene had been essentially oxidised. It is possible in the present studies that carotenoids of dehydrated carrot acted as free radical chain breakers and exerted an overall stabilising effect on lipid oxidation. Alternatively, the malonaldehyde produced during lipid oxidation of dehydrated samples did not accumulate during storage. The results of the NaCl treatment do not agree with those reported by Mabrouk and Dugan [33], who showed that NaCl inhibited oxidation of fatty acid esters in model systems. In the present studies NaCl did not affect lipid oxidation measured by the TBA method. However, this may be a reflection of the differences in information provided by the two methods of measuring lipid oxidation (i.e. peroxide values and TBA values) rather than an absolute difference in the results obtained.

From these studies it can be concluded that most of the chemicals studied had no appreciable stabilising effect on carotenoids, and only $Na_2S_2O_5$, NH_4HCO_3 and $Na_5P_3O_{10}$ afforded some protection to these pigments and increased storage life regarding carotenoid stability. A maximum storage life of 100 days was obtained for carrot treated with $Na_2S_2O_5$ solution. However, none of the treatments, including NaCl and glycerol, gave prooxidant effects. Oxygen has been postulated to be the main factor responsible for carotenoid oxidation. Lipid oxidation measured by the TBA method is apparently not affected by the chemical treatments applied. Moreover, the level of lipid oxidation found in dehydrated carrot as measured by the TBA method does not appear to warrant concern. Nevertheless, lipid oxidation is an important reaction oxidising carotenoids and producing low molecular weight off-flavour compounds with very low odour threshold values, thereby reducing the storage life of the product.

Changes in Non-enzymic Browning. The absorbance of extracts from samples treated with NH_4HCO_3, NDGA, EDTA and $Na_5P_3O_{10}$ and then dehydrated was considerably higher than that of extracts from the water dipped samples (Table 6). The higher the concentration of NH_4HCO_3 applied, the deeper was the brown colour of the treated sample. The $CaCl_2$ treatment retarded NEB whereas the $Na_2S_2O_5$ treatment inhibited completely NEB of the treated sample. However, the other chemicals showed no effect on NEB during dehydration.

With the exception of the treatments with NDGA, EDTA, $Na_5P_3O_{10}$ and NH_4HCO_3, the absorbances of the extracts from carrot treated with the remaining chemicals either increased very slowly or even decreased substantially over 90 days of storage at 37°. Such a decrease in absorbance during storage at elevated temperature suggests the occurrence of interference from carotenoid pigments present in different amounts in extracts used for measuring NEB (Tables 2 and 3). Since carotenoid pigments present in carrot tissue caused a marked error in NEB determinations of dehydrated carrot when using the alcohol precipitation method, the problem of evaluating the effect of chemical treatments on NEB rates was complicated by the presence of widely varying amounts of natural pigment in dehydrated carrots (Table 2), by the amount of pigment extracted from deteriorated and non-deteriorated samples, by the amount of bleaching of pigments during storage at elevated temperature under air and the extent of protection to natural pigments afforded by the chemicals. Thus it is quite possible that the observed NEB rates were lower than the true values, however, the chemicals which produced a substantial effect on NEB can be differentiated in such a comparative study. However, for further studies such difficulties arising from measuring NEB in the presence of both carotenoid pigments and SO_2 present in extracts of treated carrot necessitated the development of an accurate method for measuring NEB, and this was developed for subequent studies.

The NEB of carrots treated with NH_4HCO_3, NDGA, EDTA and $Na_5P_3O_{10}$ increased rapidly during storage and was maximum in carrots treated with a 1 % solution of NH_4HCO_3, whereas NEB of samples treated with

Table 6. Effect of chemical treatments on changes in NEB during storage for 180 days at 37°.

Chemical treatment	Initial NEB[a]	Increase (decrease) in NEB (absorbance $X10^3$) Storage time (days)		
		30	90	180
NDGA	189	+3	+73	+241
EDTA	171	+3	+75	+232
$CaCl_2$	116	−33	−26	+12
$Na_5P_3O_{10}$	165	+4	+41	+137
$Na_5B_4O_7$	150	−30	−10	+20
NaCl	146	−26	+41	+60
NH_4HCO_3 a(0.1%)	286	+9	+80	+529
b(1.0%)	440	+ 10	+90	+807
$Na_2S_2O_5$	72	−24	−14	− 8
Glycerol	156	− 12	+10	+54
Starch	146	−16	−6	+44
Pectin	149	−22	+3	+31
Gum arabic	153	−9	+12	+44
Water dip				
range	143–150	−11	0	+43
mean	145			
Control[b]	78	−16	−20	−30

a. Absorbance ($x10^3$) of 1.25% clarified extract in 1cm cell at 420 nm; b. Sulphited, stored in nitrogen at − 12°.

glycerol, starch, pectin and gum arabic increased only very slowly during 180 days of storage at 37°, the extent of NEB being similar to that in the reference samples. The extent of NEB of carrots treated with $CaCl_2$ and $Na_2B_4O_7$ was reduced considerably, whereas it was inhibited completely in carrots treated with $Na_2S_2O_5$. The finding that treatment with $CaCl_2$ retarded NEB in dehydrated carrot is in agreement with results reported for dehydrated white potatoes [4]. It has been reported that $Na_2B_4O_7$ complexes with sugars [34] and hence should be expected to retard NEB of dehydrated fruits and vegetables prepared commercially [35–39].

With the exception of treatment with $Na_2S_2O_5$ which is well known to be very effective for inhibiting NEB, the effect of the other chemicals on NEB has not been reported previously. $CaCl_2$ and $Na_2B_4O_7$ treatments can also be used as NEB retardants. Treatment with NH_4HCO_3, EDTA or $Na_5P_3O_{10}$ was found to produce a brown colour after dehydration, and discolouration increased rapidly on subsequent storage. The remaining treatments with NaCl, glycerol, starch, pectin and gum arabic had little effect on NEB.

Changes in Rehydration Capacity. Irrespective of the treatments applied, considerable loss in rehydration capacity (i.e, ratio of the drained weight of rehydrated carrot to the weight of fresh carrot equivalent to the weight of dehydrated carrot used for rehydration) was observed after dehydration, in contrast to minor losses found during subsequent storage of samples for 180 days at 37° (Table 7). Only 46.2 – 60.2% of initial weight was restored when carrots were rehydrated immediately after dehydration, whereas additional losses in rehydration capacity of only 2.2 – 13.7 % occurred during storage for 180 days at 37°. Such high losses are expected since macromolecular components such as cellulose pectin, hemicelluloses and proteins responsible for such properties [40,41] are adversely affected during pre-dehydration and dehydration processes [42–46].

A maximum loss of 53.8 % and 13.7 % of the original weight of carrot treated with $CaCl_2$ occurred during dehydration and during subsequent storage respectively. The high loss with this treatment is to be expected as $CaCl_2$ firms the tissues [4]. A minimum loss of 39.8 % and 2.2 % occurred as a result of dehydration and subsequent storage in carrot treated with $Na_2B_4O_7$. The loss during storage in this case was 6.2 times less than that found in carrot treated with $CaCl_2$ and stored under similar conditions, and is almost equal to that observed in the control sulphited sample

Table 7. Effect of chemical treatments on loss of rehydration capacity of dehydrated carrot during storage at 37°.

Chemical treatment	Loss of rehydration capacity (%)				
	During dehydration	During storage at 37° Storage time (days)			Total
		30	90	180	
NDGA	51.0	1.8	4.6	6.6	57.6
EDTA	51.4	2.5	3.9	5.6	57.0
$CaCl_2$	53.8	5.2	11.2	13.7	67.5
$Na_5P_3O_{10}$	53.5	1.8	4.6	6.2	59.7
$Na_2B_4O_7$	39.8	0.7	1.2	2.2	42.0
NaCl	50.5	1.3	2.9	5.3	55.8
NH_4HCO_3	–	–	–	–	–
$Na_2S_2O_5$	49.1	1.5	2.6	3.4	52.5
Glycerol	–	–	–	–	–
Starch	50.2	1.0	3.3	5.1	55.3
Pectin	50.5	1.4	4.0	6.6	57.1
Gum arabic	51.7	1.1	2.6	5.0	56.7
Water dip[a]	49.5	1.2	2.5	5.0	54.5
Control[b]	48.8	0.6	1.0	1.7	50.5

a. Mean of seven samples; b. Sulphited, stored in nitrogen at – 12°.

stored in nitrogen at – 12°. Since it has been observed that $Na_2B_4O_7$ expands on heating while losing water of crystallisation and because of its known reactivity with carbohydrates, these properities of $Na_2B_4O_7$ could account for its ability to inhibit to some extent the collapse of cells as normally occurs during dehydration. From these studies it appears that the major loss in rehydration capacity of dehydrated carrot occurs during dehydration. Although losses continued throughout the storage period, total losses during storage were minor compared to losses during dehydration. The rehydration capacity of carrot treated with $Na_2B_4O_7$ was highest, while carrot treated with $CaCl_2$ showed the lowest rehydration capacity.

CONCLUSIONS

From these studies it is concluded that coating the surface of carrot with pectin, gum arabic and starch had little effect on the overall stability of dehydrated carrot. Antioxidants such as EDTA and NDGA slightly improved the carotenoid stability, but increased NEB. Although $Na_5P_3O_{10}$ reduced carotenoid breakdown to some extent, its use increased NEB, and to other treatments and to the control. Treatment with sulphite proved to be effective in retaining overall quality of dehydrated carrot during storage, as it reduced losses in carotenoid pigment, controlled NEB completely and reduced to some extent changes resulting in loss of rehydration capacity. Treatments with $Na_2S_2O_5$ and $Na_2B_4O_7$ were found, overall, to be more effective in retaining quality of dehydrated carrots than the other treatments studied.

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