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Effect of salt iodization on the quality of pickled vegetables

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Abstract

Vegetables were pickled in 100 g L^{-1} brines prepared from refined and crude table salt (NaCl) obtained from the Dead sea and natural brine wells (wet-mined) with and without the addition of 40 mg kg^{-1} iodine in the forms of KIO_3 or KI. The effect of iodine form, salt source and refining on the sensory quality, iodine content and vitamin C content of the pickles, as well as vitamin A content of carrot pickles was studied. Sensory evaluation results indicated that iodization has no effect on the taste of the pickles, while the addition of KIO_3 to both crude and refined salt resulted in significant (P=0.05) darkening and discoloration of most pickled vegetables regardless of the salt source. Addition of KIO_3 also resulted in significant ($P<0.05$) softening of the pickles prepared from both crude and refined Dead sea salt, while this effect was less pronounced in the case of the wet-mined salt. None of these negative effects was noticed when potassium iodide was used. The process of pickling also resulted in great reduction in vitamin C levels in the pickled vegetables, and a similar reduction in vitamin A level in pickled carrots, while the process of iodization had no pronounced effect on the pickle content of these vitamins regardless of the salt source or refining. Iodine concentration in the pickled vegetables reached levels of 1.60-1.80 mg kg^{-1} or about 40-45% of its initial concentration in the respective brines, regardless of the type of salt used or the form of iodine added, while iodine concentration in the brines reached 1.6-2.1 mg kg^{-1} after the same period.

Key words: Pickles, salt, iodization, potassium iodate, potassium iodide.

Introduction

Iodine deficiency disorders are well known, they are manifested in the form of goiter, reduction in IQ and even mental retardation and cretinism. To alleviate these disorders, international health agencies have been recommending the iodization of table salt at a level of 40 mg kg^{-1} for countries where needed [1]. It had been reported that 37.7% of Jordanian children between 8-10 years of age suffer from iodine deficiency disorders [2]. To counteract this problem, Jordan launched a national salt iodization program through which iodization became mandatory to a level of 40-60 ppm iodine at the factory level[3].

Iodine is usually added to salt in the form of potassium iodide, cuprous iodide or potassium iodate. The latter form is preferred in the countries with warm climates as it is more stable than the iodide form under such conditions, hence potassium iodate was chosen as the iodine source for salt iodization in Jordan. Since the initiation of the salt iodization program, a number of complaints have been voiced by food processors in Jordan to the effect that iodine addition to the salt resulted in the discoloration and softening of pickles, in addition to other problems related to other foods .

Iodine addition was reported by some workers to adversely affect the properties of foods prepared with iodized salt to the extent that some workers recommended that no iodized salt should be used in food processing [4]. The adverse effects of iodine on foods include discoloration of pickles[5] and undesirable changes in the flavor of canned tomato juice [4]. On the other hand, other reports assert that iodine addition has no adverse effects on the quality of bakery products[6], cheese [7], sausages [8], pickles [2] and cooked rice and potatoes [9].

Salt is produced from a number of sources worldwide, these include sea water, deep wells (natural brine, or wet-mined salt) and salt rocks. In Jordan, all three sources are utilized, although about 90% of the commercially available salt is obtained by the first method [3].

Although stability of iodine was studied in a number of heat-treated foods [6], none-the-less, it was not studied thoroughly in pickled vegetables as pickles are not subjected to rigorous heat treatment that may result in its loss. Hence the objective of this work was to study the effects of source of salt, refining and iodization with two forms of iodine (KI and KIO_3) on the quality of the pickles produced as well as their vitamin C and iodine content. In addition, the effect of the pickling process on vitamin A content of carrots was studied as carrots are a major source of this vitamin.

Materials and Methods

Vegetables: Cucumbers, turnips, carrots, cauliflowers, and olives were purchased from a local market. The former four vegetables were trimmed and prepared for pickling manually, with turnips being peeled and sliced.

Salt and brine preparation: Crude and commercially-refined salt samples from two sources (Dead sea and wet-mined) were obtained from the two major salt companies dealing with the respective salts. Each sample was divided further into 3 sub-samples, one was used as a control and the other two were treated each with KI or KIO_3 to a level of 40 mg kg^{-1} as iodine ion. A total of 12 salt treatments were obtained. Salt solutions (brines) at concentrations of 100 g kg^{-1} were prepared from each salt treatment.

Pickle preparation: Two 500 g-portions (replicates) from each of the five vegetables were pickled in each type of brine in one litre glass jars at room temperature for a period of 12 days (until done), after which they were tested for sensory quality. Samples were also taken daily for determination of the salt and iodine content of both the pickles and the brines.

Salt content of brines and pickles: The salt content of the brines was determined using a hydrometer (Salometer), while that of pickles was determined following the AOAC method # 971.27 [10].

Mineral content of the salts: Bromine was determined according to the ASTM volumetric method # D3869-79 [11]. Magnesium and calcium content of the salt was determined according to ISO method # 2482 [12]. Iron was determined following the AOAC method # 965.09[10] using an atomic absorption spectrophotometer (A.A.S. Solar, Unicam 939).

Iodine level in pickles and brines: Iodine level in the brine and pickles was determined according to the AOAC method # 925.56[10]. Ten gram-samples of the pickles were extracted in 100 ml of distilled water, and 10 ml of the brine was taken for each assay. The same method was used for assaying the iodate and iodide-treated salt samples with the variation stated for each in the reference method. All results were expressed as I_2 mg kg^{-1} of pickled vegetables or I_2 mg L^{-1} of brine.

Vitamin C and A in pickles: Vitamin C level in all fresh vegetables as well as in the pickles was assayed following the AOAC method # 967.21[10]. Values were expressed as L-ascorbic acid mg kg^{-1} vegetable. Vitamin A was assayed in carrots only following the AOAC method # 941.15 [10]. Values were expressed as vitamin A mg kg^{-1} carrots.

Sensory evaluation of the pickles: Sensory evaluation of the pickles was conducted through a taste panel consisting of 10 trained members who were asked to rank the score of each quality factor (taste, color and texture) on a hedonic scale of (1-10), one being very poor and ten being excellent.

Statistical analysis: Analysis of variance was performed on all results using a SAS program [13]. Duncan Multiple Range Test was applied for comparing the means of the variables which were significant.

Results and Discussion

Quality of the salts used in the study: Table 1 shows the iron, magnesium, calcium, bromine and sulfate content of the salts used in the study. Crude Dead sea salt had higher levels of magnesium and bromine (i.e. 1220 and 358 mg kg^{-1} respectively) than the salt from the other source. The refining process of the Dead sea salt resulted in reducing the bromine and magnesium levels to about 50% and 1% of their original levels respectively. This is due to the soluble nature of their salts which are present mainly in the form of chlorides. Both ions were higher in the crude salt taken from this source than in the crude wet-mined salt where the bromine and magnesium levels were 35 and 420 mg kg^{-1} respectively. The Dead sea crude salt contained iron 26, calcium 2500 and sulfate 3000 mg kg^{-1}. The refining process resulted in about 50, 60 and 99% reduction of the original iron, calcium and sulfate content of this salt respectively.

Table 1. Concentration of Fe, Mg, Ca, Br and SO_4 in the salt samples.*

	Dead sea salt Crude	Refined	Wet-mined salt Crude	Refined
Fe	26	6	50	11
Mg	1220	12	420	25
Ca	2500	890	3800	1300
Br	358	174	35	29
SO_4	3000	20	37000	4400

*(mg kg^{-1})

The wet-mined salt contained much less magnesium and bromine but more iron, calcium and sulfate. The refining process resulted in reduction of all ions in this case. However, this salt contained higher levels of calcium, magnesium and sulfate than the Dead sea salt despite the refining process; the latter was higher only in its bromine content. Codex standard for table salt intended for iodization allows maximum levels of 2000, 1000 and 5000 mg kg^{-1} of calcium, magnesium and sulfate respectively [14]. On the other hand, Jordan standard for table salt specifies no limits for maximum magnesium, calcium and sulfate, while it sets the maximum level for iron at 20 mg kg^{-1}, and the sodium chloride content at 98.5% [15]. All of our refined salt samples conformed to this standard.

Change in salt levels in cucumber pickles and brine: Figures 1 and 2 show the changes in salt levels in cucumbers and brine respectively during the process of pickling. Neither the source of salt nor the addition of iodine had significant effects on the rate at which salt penetrates the cucumbers or leaves the brine regardless of the form of iodine added. The salt in pickles and brines reached the equilibrium level of 4-5% after about 12 days from the start of the pickling process regardless of the type of salt or form of iodine used.

Effect of iodization on the iodine content of pickles: The iodine content of the pickles after the 12th day of pickling ranged from 1.6 to 1.8 mg kg^{-1} regardless of the salt source, refining or form of iodine added (Figs 3-4). The iodine level was slightly higher in cucumbers and turnips than in carrots and cauliflowers, which is due to the soft skins of the former two vegetables as compared to the latter two, and the consequent ease of salt penetration. It was also noticed that the iodine level in pickles increased considerably from the first day to reach a constant level of 1.6-1.8 mg kg^{-1} around the tenth day of pickling. Furthermore, in case of almost all vegetables and the two salt sources, iodine concentration in pickles was higher when refined salt rather than crude salt was used.

Iodine level in the brine was about 4 mg L^{-1} at the beginning of the process and decreased with pickling time to reach a level of 1.6-2.1 mg L^{-1} towards the end of the pickling period (Figs 5-6). The brines of the pickles with lower iodine concentrations (i.e. carrots and cauliflower) had the highest iodine levels, indicating the slower iodine penetration rate into these vegetables which is due to their hard skins as compared to the skins of cucumbers and peeled turnips. The iodine level in both the brine and the pickles reached equilibrium around the 8th day of pickling only in case of the cucumber pickles, while it remained higher in the brine throughout the pickling process in the case of the other vegetable pickles.

Pickle taste and color: Analysis of variance indicated that treatments at these levels of iodine had no significant effect ($P \leq 0.05$) on the taste of all pickled vegetables as indicated by the taste panel scores. The mean color scores obtained by each vegetable pickle and comparison of means by Duncan Multiple

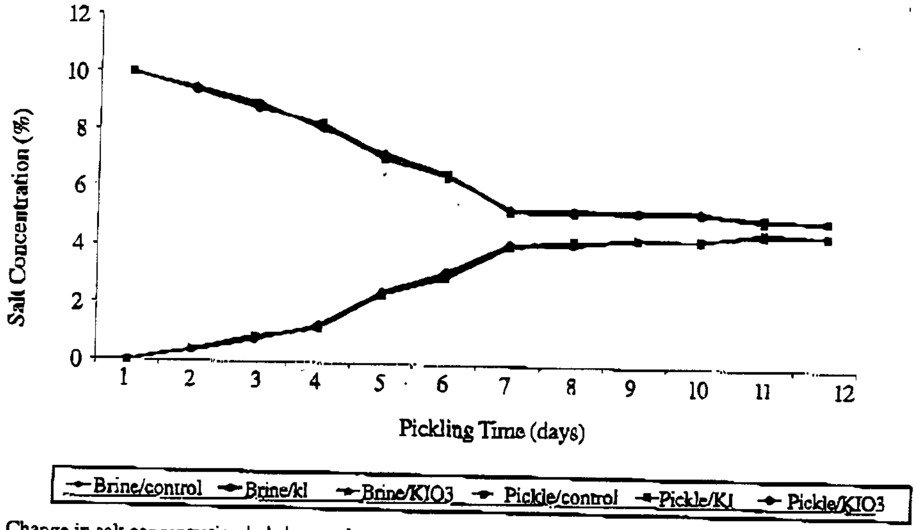

Figure 1. Change in salt concentration in brines and cucumber pickles prepared from Dead sea salt iodized with KI and KIO_3.

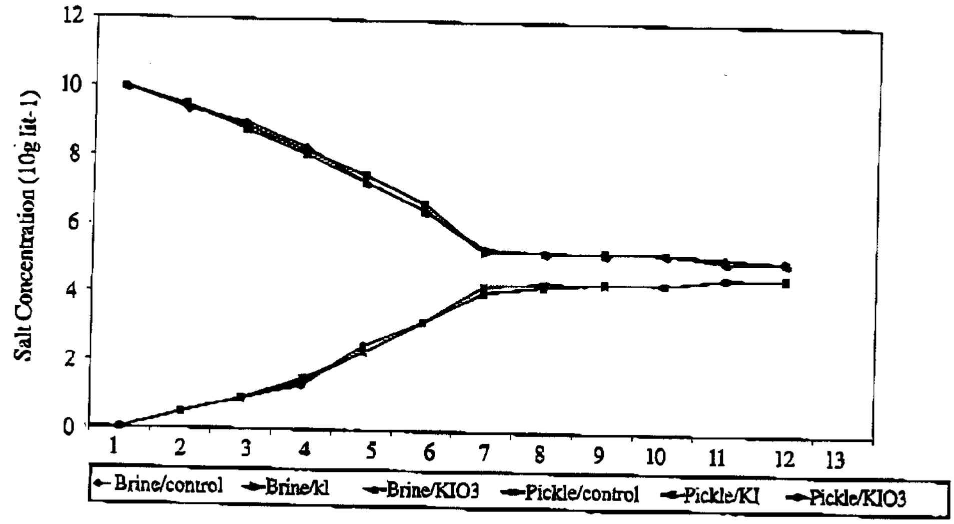

Figure 2. Change in salt concentration in brines and pickles prepared from wet-mined salt during pickling.

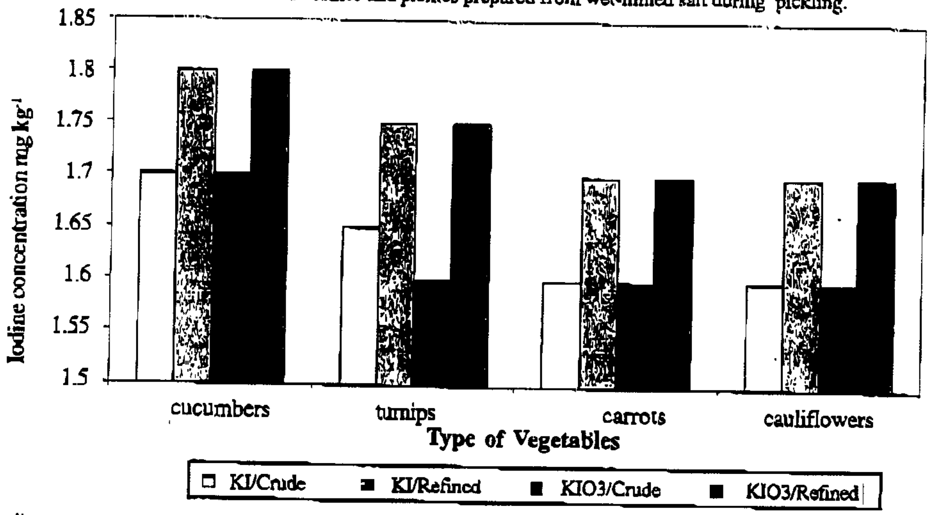

Figure 3. Iodine concentration in pickles prepared with wet-mined salt iodized with KI and KIO_3 after 12 days pickling.

Range test are presented in Table 2. It appears that color scores of pickles prepared with iodate-treated salt were significantly lower (pd≤0.05) than those of the pickles prepared with the iodide-treated and the control salts. The only exception was the color scores of olive pickles which were not significantly (P.d≤0.05) influenced by iodate treatment when refined salts were used. The observed negative effects were in the form of dull dark colors of the iodate-treated pickles, especially the light–colored pickles, as compared to the iodide-treated pickles or the controls. It is expected that some of the iodate is broken down during storage of the pickles, as breakdown of iodate during salt storage is well documented [16]. The liberated iodine is also expected to complex with the starch in the pickles and give the observed color.

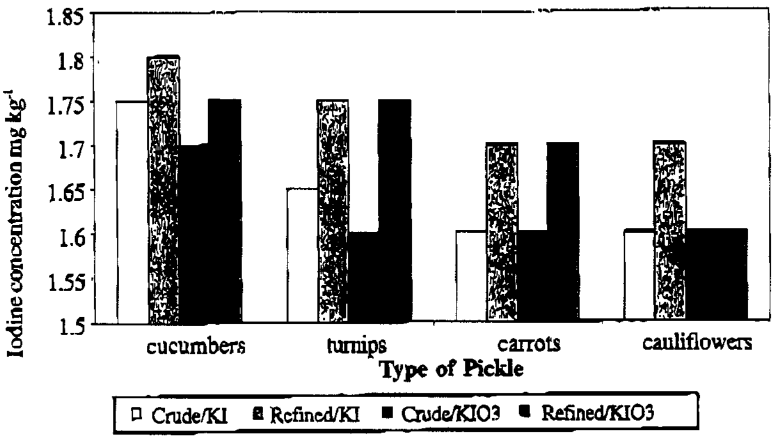

Figure 4. Iodine concentration in pickled vegetables prepared with Dead sea salt iodized with KI and KIO3 after 12 days of pickling.

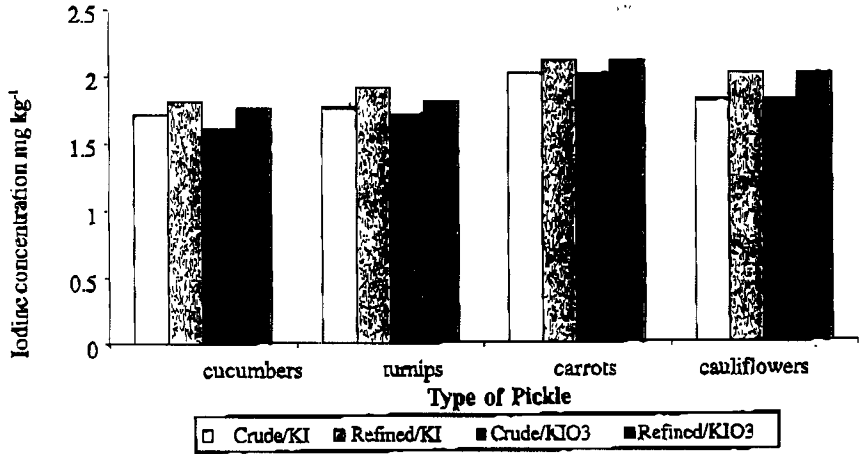

Figure 5. Iodine concentration in the vegetable-pickle brines prepared with Dead sea salt iodized with KI and KIO_3 after 12 days of pickling.

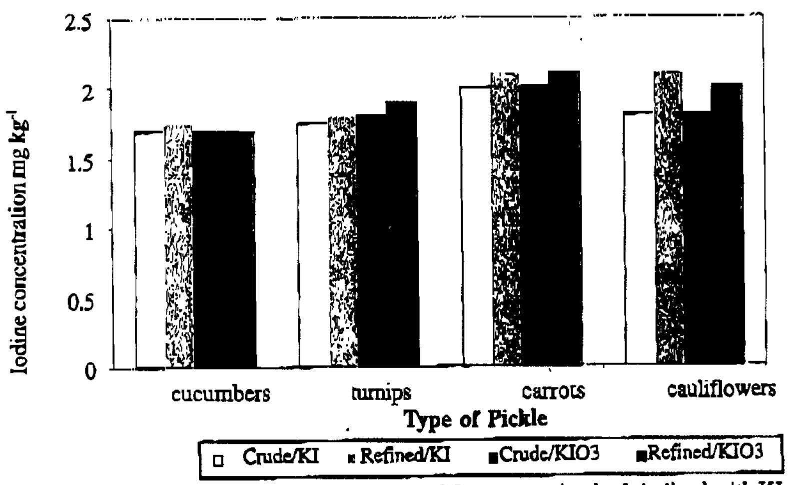

Figure 6. Iodine concentration in pickled vegetable brines prepared from wet-mined salt iodized with KI and KIO_3 after 12 days of pickling.

Pickle texture: Table 3 shows that in general, the texture scores of most vegetable pickles prepared with iodate–treated salts were significantly (Pd≤0.05) lower than the scores of the pickles prepared with the control or with the iodide-treated salts regardless of their source. This was accompanied by more gas production which implies oxidation of the methyl groups in the pectin molecules by the iodate and the accompanying CO_2 production. The negative effect of iodate which appeared in the form of softening of these pickles was less pronounced in case of the vegetables prepared with the iodate-treated, wet-mined, refined salt due to high calcium ion content which is known of its firming effect on vegetables [17].

Vitamin A content of carrots: Carrots pickled in noniodized refined wet-mined salt contained 3,000 mg kg^{-1} β-carotene (6,000 retinal equivalents) compared to 38,000 mg kg^{-1} β-carotene (76,000 retinal equivalents) in the raw carrots. Iodine addition resulted in slight lowering of the β-carotene content to about 2900 and 3000 mg kg^{-1} when both KIO_3 and KI were used respectably. The difference between the control samples and the treatments in their vitamin A content lies within the experimental error.

Vitamin C: Table 4 shows that vitamin C loss due to the pickling process ranged from 62.5% in cucumbers to 93.5% in turnips as

Table 2. Mean color scores of the pickles prepared with the various types of salt.*

Salt type	Dead sea salt						Wet-mined salt					
	Crude			Refined			Crude			Refined		
Pickle	Control	KI	KIO_3	Control	KI	KIO_3	Control	KI	KIO_3	Control	KI	KIO_3
Cucumber	6.9^{a}	7.0^{a}	5.4^{b}	7.0^{a}	7.0^{a}	6.7^{b}	6.8^{b}	8.0^{a}	4.2^{c}	7.0^{a}	7.5^{a}	5.8^{b}
Carrot	7.2^{a}	6.8^{a}	6.1^{b}	7.0^{a}	7.6^{a}	5.3^{b}	8.0^{a}	8.1^{a}	6.0^{b}	6.8^{b}	7.4^{a}	7.1^{a}
Cauliflower	7.1^{a}	7.2^{a}	4.1^{b}	7.2^{a}	7.2^{a}	4.5^{b}	7.3^{a}	7.1^{a}	6.0^{b}	7.2^{a}	6.9^{a}	5.1^{b}
Turnip	6.8^{a}	6.6^{a}	4.2^{b}	6.8^{a}	6.5^{a}	4.9^{b}	6.1^{a}	6.3^{a}	5.3^{b}	8.4^{a}	7.6^{b}	6.6^{c}
Olive	7.0^{a}	7.2^{a}	6.2^{b}	7.0^{a}	7.6^{a}	7.3^{a}	7.0^{a}	7.3^{a}	6.1^{b}	7.0^{a}	6.9^{a}	6.9^{a}

* Means within the same type of salt and row with the same letter are not significantly different at the 5% level of probability according to Duncan's Multiple Range test. Each value is the average of 10 readings that are not significantly different ($P \leq 0.05$).

Table 3. Mean texture scores of the pickles* prepared with the various types of salt.

Salt type	Dead sea salt						Wet-mined salt					
	Crude			Refined			Crude			Refined		
Pickle	Control	KI	KIO_3	Control	KI	KIO_3	Control	KI	KIO_3	Control	KI	KIO_3
Cucumber	7.2^{ab}	7.9^{a}	6.8^{b}	7.0^{a}	7.1^{a}	6.9^{a}	7.0^{a}	6.9^{a}	6.3^{b}	7.8^{a}	7.1^{ab}	6.8^{b}
Carrot	7.8^{a}	7.8^{a}	6.1^{b}	7.4^{a}	7.6^{a}	7.3^{a}	7.2^{a}	7.1^{a}	6.5^{b}	6.8^{b}	7.4^{a}	7.4^{a}
Cauliflower	7.2^{a}	7.4^{a}	6.1^{b}	7.2^{a}	7.3^{a}	6.5^{b}	7.7^{a}	7.0^{ab}	6.6^{b}	7.2^{a}	7.1^{a}	7.1^{a}
Turnip	5.1^{a}	4.6^{b}	4.2^{c}	6.1^{a}	5.4^{b}	4.9^{b}	6.7^{a}	6.8^{a}	6.5^{a}	6.7^{a}	5.0^{b}	6.6^{a}
Olive	7.5^{a}	7.4^{a}	6.2^{b}	7.2^{a}	7.1^{a}	7.3^{a}	7.4^{a}	7.3^{a}	7.1^{a}	7.5^{a}	7.3^{a}	7.2^{a}

* Means within the same type of salt and row with the same letter are not significantly different at the 5% level of probability according to Duncan's Multiple Range test. Each value is the average of 10 readings that are not significantly different ($P \leq 0.05$).

Table 4. Vitamin C concentration mg kg^{-1} of the pickles.

	Fresh vegetable	Vegetables pickled in Dead sea salt						Vegetables pickled in wet-mined salt					
		Crude			Refined			Crude			Refined		
		Control	KI	KIO_3	Control	KI	KIO_3	Control	KI	KIO_3	Control	KI	KIO_3
Cucumber	230	50.0	62.5	50.0	62.5	62.5	62.5	75.0	75.0	75.0	50.0	56.0	50.0
Carrot	300	35.0	35.0	32.5	35.0	35.0	35.0	35.0	35.0	31.3	35.0	35.0	35.0
Cauliflower	600	125.0	125.0	112.5	120.0	120.0	120.0	125.0	122.5	125.0	125.0	112.1	125.0
Turnip	220	30.0	30.0	36.0	33.0	33.0	32.5	39.0	33.0	33.0	32.05	35.0	38.0
Olive	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

compared to their raw counterparts. Neither the source of salt nor the form of iodine added seemed to have a pronounced effect on the vitamin C content of these vegetables.

Conclusions

Salt iodization has no significant effect ($P \leq 0.05$) on neither the rate at which the salt penetrates through the pickled vegetables nor the iodine content of the pickles regardless of the source of salt or form of iodine added. Iodization of the salts obtained from the Dead sea and brine wells has no adverse effects on the taste of the pickled vegetables regardless of the iodine form added. The color scores of almost all pickles prepared with iodate-treated salt were significantly ($Pd \leq 0.05$) lower than those of the pickles prepared with iodide-treated salt at a level of 40 ppm iodine regardless of the source of salt used. The use of iodate with the salts obtained from the two sources resulted in significantly ($Pd \leq 0.05$) softer pickles. However this adverse effect was less pronounced when the high-calcium refined wet-mined salt was used. The effect of iodine on the quality of pickled vegetables depends on the type of vegetable, the metal impurities in the salt. The form of iodine added as iodate has more negative effects on pickle color and texture than iodide ion. Salt iodization has no significant effect on both vitamin C and A content of the vegetables regardless of the form of iodine used, while the pickling process resulted in great reductions in the pickle-content of these two vitamins.

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