Effects of Sodium Metabisulphide Treatment and Modified Atmosphere Packaging on Cold Storage of Carrots

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Abstract: The aim of this study was to investigate the effects of sodium metabisulphide (SMBS) treatment and modified atmosphere packaging (MAP) on the quality of 'Nanco F1' variety of Nantes group carrots grown in Kırıkhan during cold storage. Harvested carrots were placed in imperforated bag, and/or MAP and applied SMBS (dose of 1%) after washing with tap water for 3 minutes and stored at 0±0.5 °C and 90±5.0% relative humidity for 5 months and analyzed every month. In addition, carrots were kept at 20±0.5 ºC and 75±5.0 % relative humidity for 7 days in order to study its shelf life. The weight loss, carrot color (L* and h°), appearance (1-9), rooting and sprouting rate, rooting and sprouting degree, incidence of fungal decay, physiological disorders, carrot firmness, total soluble solid content, pH value, titratable acid content and taste (1-9) were determined during shelf life and storage. According to the findings, weight loss in imperforated bag was higher than MAP treatments during storage. It was determined that using ImPBTW (imperforated bag and washing with tap water) and ImPBTW + SMBS treatments, 'Nanco F1' type carrots could be kept at 0 °C for 3 months and 85-90% relative humidity without any quality deterioration. It was also determined that using MAPTW (modified atmosphere packaging and washing with tap water) + SMBS treatment, 'Nanco F1' type carrots could be stored for 4 months and using MAPTW treatment, they could be stored for 5 months at 0 °C and 85-90% relative humidity without losing much of the quality for local and distant markets. Also, it was found that SMBS treatments were not sufficient to prevent rooting and sprouting.
Keywords: Carrot, sodium metabisulphide, MAP, cold storage, shelf life, quality

1. Introduction

New technologies are needed to reduce loss of taste and flavour, to prevent bitterness and to reduce fungal decay during storage while preserving quality of fruits and vegetables. In a study investigating quality losses in carrots, it was determined that the losses before and during the harvest were high. In particular, 49.45% of first class/quality carrots which are prepared and sent in and out of the country discarded and it is indicated that there are a number of problems starting from breeding [1]. In carrots storage, clean stores should be used in the storage, the temperature should be kept close to 0 °C and the relative humidity should not be more than 95% [2, 3, 4]. The Modified Atmosphere Packing (MAP) technique is a method of product preservation and packaging which has a growing demand for safe, pure and high nutritional value products for consumers. The quality of the products can be preserved for a longer time and the shelf life can be extended with the selection of proper atmospheric composition, packaging material and storage conditions in MAP technique [5, 6]. Aluminum and bisulfite salts are toxic to several microorganisms including fungi [7, 8, 9] and bacteria [10, 11]. SMBS is an inorganic salt and used as a food preservative in food products [12]. But, high concentrations of SMBS could have negative effects on fruits. SMBS when dissolved in water is converted to sodium bisulfite and sulfur dioxide. Dipping tomatoes in 6% or 8% SMBS for 5 min before drying was reported to have established the best color [13]. The standard practice to control postharvest decay of grapes worldwide is to fumigate the fruit after harvest with SO_2 gas [14, 15, 16, 17]. The objective of this study was to study the improvement possibility of the storage conditions of 'Nanco F1' carrot variety from Nantes group carrots grown in Kırıkhan region of Hatay Province by using SMBS and MAP technique.

2. Material and methods

In this study, carrots from the 'Nanco F1' carrot variety in the Nantes group grown in Kırıkhan region of Hatay province were used. The carrots were supplied from the production site of a producer (Sedef Tarım Coop.). The carrots were sorted and selected for uniform size and appearance and absence of defects. Carrots were placed in imperforated bag and/or modified atmosphere packaging (MAP: Life Pack® with 5 kg MAP bags) and immersed in 1% sodium metabisulphide (SMBS) after washing with tap water for 3 minutes (Figure 1). SMBS (chemical formula $Na_2S_2O_5$, molecular weight 190.10 and CAS no. 7681–57–4) was obtained from Carlo Erba Reagents (code no: 370752). After the carrots were dried, they were put in 10 kg imperforated bags and 5 kg MAP bags (ImPBTW: imperforated bag and washing tap water for 3 minutes, MAPTW: MAP and washing tap water for 3 minutes, ImPBTW + SMBS: imperforated bag and immersing in 1% sodium metabisulphide after washing with tap water for 3 minutes, MAPTW+ SMBS: MAP and immersing in 1% sodium metabisulphide after washing with tap water for 3 minutes). Then, the products were stored in a cold storage at 0 °C and at 90-95% relative humidity for 5 months. In addition, the carrots were stored at 20 °C for 7 days each month to determine the shelf life of the fruit.

Weight loss: During storage the carrots with the bags were weighed with a scale (AND GX-20K, Tokyo, Japan) sensitive for 0.2 g and a weighing capacity of 16 kg. To determine the shelf life, 30 carrots were numbered individually and weighed with a precision scale (Ohaus Adventurer, USA) sensitive to 0.01 g per month. The weight loss was expressed as a percentage.

Figure 1. SMBS treatment (top), MAP treatment (middle) and ImPBTW treatment (bottom)

Appearance and taste (1-9): Samples taken each month from the carrots that were stored at storage and shelf conditions was assessed by a panel of 10 panelists (non-smoker 7 male and 3 female, ages 20 to 45) according to the hedonic scale. The grade scale ranging from 1 (worst) to 9 (best) was used. "5" on the scale was considered as the limit of being marketable [18].

Incidence of fungal decay and physiological disorders: The carrots that were stored at storage and shelf conditions were evaluated individually and fungal deterioration and physiological disrders were determined. The decay rates were expressed as a percentage.

Carrot color (L* and h°): Every month, the color of the carrots from the storage and shelf life conditions were measured base on C.I.E. According to L* a* b* color model using a chromameter (Minolta CR-300 model, Konica Minolta Sensing Inc., Osaka, Japan). The color data was read from the stem and both sides of 5 cm below the head of each carrot [19].

Rooting and sprouting rate: The carrots that were stored at the storage and shelf conditions were evaluated individually, the ratio of forming roots and shoots of carrots during storage was determined as a percentage.

Rooting and sprouting degree: The number and length of shoots and roots formed on the carrots according to scale 0-5 was taken into account [20]. The length of shoots and roots was measured in cm with a digital caliper and then used for evaluation.

Carrot firmness: During storage condition and shelf life, carrot firmness was measured by using a penetrometer (Effegi model FT 444, Italy) having a drilling head with a length of 6 mm. The firmness was measured after removing a thin layer with a diameter of approximately 1 cm on both sides, 5 cm below the head of each carrot and then the values were converted to Newton (N).

pH value: The pH level was measured with a digital pH meter (Thermo Fisher Scientific Inc., MA, USA) during the storage and shelf conditions.

Titratable acidity content (TA): The potentiometric method [21] was used in the storage and shelf life conditions. 5 ml of sample obtained from the carrot juice obtained was 100 ml with distilled water and 8.1 of the digital pH meter was titrated with 0.1 N NaOH solution (Brand titrette, Germany). The results were calculated as citric acid / g citric acid / 100 ml fruit juice.

Total soluble solid content (TSS): TSS was determined as a percentage with a hand refractometer (Atago ATC-1E Model, Atago Co. Ltd., Tokyo, Japan).

For the carrot samples taken every month during the storage and shelf life conditions, 2 kg of carrots were analyzed three times for each time and every application. The research was planned according to the "factorial experiment in a completely randomized block design" and the data acquired were analyzed by using the SAS software (Version 9.4, SAS Institute, Cary, N.C.) [22]. Tukey test ($p < 0.05$) was employed for comparison and the results are given in the tables.

3. Results and discussion

An increase in weight loss was detected when the storage time of the 'Nanco F1' variety carrots was prolonged and reached an average of 7.45% in the 5th month. Among the treatments, weight loss was the lowest in MAPTW+ SMBS (4.03%) and MAPTW (4.22%) treatments while weight loss was the highest in ImPBTW + SMBS (4.69%) and ImPBTW (4.56%). As the shelf-life prolonged, the average weight loss increased from 0.73% at the beginning to 1.29% at the fourth month and then decreased to 1.01% at the end of the fifth month. Weight loss between treatments during shelf life conditions was the highest in the treatment of MAPTW, and the lowest with treatment of ImPBTW (Table 1). In general, if the weight loss rate exceeds 10% of the total weight of the product, the product may be considered as unmarketable. In none of the treatments included in the study, weight loss exceeded 10% at the end of 5 months.

As the storage period of the carrots was prolonged, there had been a decrease in the appearance scores according to the 1-9 scale and decreased below the acceptable limit of 5 at the end of 5th month (4.58). Among the treatments, MAPTW+ SMBS and MAPTW treatments provided the best appearance scores during storage and did not decrease below the acceptable limit. As the shelf-life prolonged, the average appearance scores decreased from 8.78 at the beginning to 5.75 at the third month and then decreased below the acceptable limit of 5 at the end of 4th and 5th months (3.64 and 2.25 respectively). Appearance scores between treatments during shelf life were the highest in the treatment of MAPTW and the least with the treatment of MAPTW+ SMBS (Table 1). Similar findings were reported by different investigators that appearance scores reduced during storage [3, 4, 23, 24].

As the storage time of the 'Nanco F1' variety carrots was extended, the taste scores decreased according to the scale of 1–9 and fell below the acceptable limit of 5 at the end of 5th months (4.17). Among the treatments, MAPTW and MAPTW+ SMBS treatments gave the best taste scores during storage and did not fall below the acceptable limit at the end of storage. As the shelf-life prolonged, the average taste scores decreased from 8.78 at the beginning to 5.72 at the third month and then decreased below the acceptable limit of 5 at the end of 4th and

5th months (3.89 and 2.25 respectively). Taste scores between treatments during shelf life were the highest in the treatment of MAPTW and the lowest with treatment of MAPTW+ SMBS (Table 1). Similar findings were reported by different investigators that taste scores reduced during storage [3, 4, 25, 26, 27].

Table 1. Effects of treatments on weight loss, appearance, taste, fungal decay, carrot firmness, carrot color values in 'Nanco F1' type carrots during 5 months of storage at 0 °C and 7 days of shelf life at 20 °C

Storage type	Weight loss (%)	Appearance (1-9)	Taste (1-9)	Fungal decay (%)	Carrot firmness (N)	L*	h°
Cold storage treatments							
ImPBTW	4.56 a[x]	6.50 b	6.35 b	0.00 b	96.25 a	41.43 c	54.11 b
MAPTW	4.22 b	7.22 a	7.48 a	0.00 b	93.37 a	51.57 a	54.33 b
ImPBTW + SMBS	4.69 a	6.54 b	6.56 b	5.33 a	97.06 a	41.16 c	56.04 a
MAPTW+ SMBS	4.03 b	7.39 a	7.28 a	0.00 b	94.64 a	49.72 b	55.14 ab
Cold storage time (Months)							
0	---	9.00 a	9.00 a	---	99.67 a	47.91 b	52.08 c
1	1.55 e	8.47 b	8.58 b	0.00 b	100.48 a	45.29 c	54.39 b
2	3.06 d	7.86 c	7.83 c	0.00 b	100.54 a	47.98 b	54.99 ab
3	3.94 c	6.28 d	6.28 d	0.00 b	97.76 a	52.19 a	56.46 a
4	5.89 b	5.28 e	5.64 e	0.00 b	90.64 b	45.69 c	55.17 ab
5	7.45 a	4.58 f	4.17 f	6.67 a	82.89 c	36.79 d	56.34 a
Shelf life treatments							
ImPBTW	0.75 d	6.17 b	6.30 b	11.67 a	99.19 b	52.48 a	51.61 b
MAPTW	1.26 a	6.46 a	6.74 a	0.00 b	94.07 c	53.09 a	53.80 a
ImPBTW + SMBS	1.09 b	5.63 c	5.65 c	3.33 b	98.73 b	48.49 b	51.10 b
MAPTW+ SMBS	0.96 c	5.17 d	5.19 d	2.22 b	105.08 a	51.50 a	55.02 a
Shelf life time (Months+days)							
0+7	0.73 d	8.78 a	8.78 a	0.00 b	100.27 a	56.42 a	50.24 d
1+7	1.00 c	8.14 b	8.28 b	0.00 b	100.48 a	52.29 b	52.94 bc
2+7	0.96 c	6.58 c	6.89 c	0.00 b	100.07 a	51.08 b	54.27 ab
3+7	1.12 b	5.75 d	5.72 d	0.00 b	98.46 a	51.02 b	55.65 a
4+7	1.29 a	3.64 e	3.89 e	2.50 b	98.73 a	50.83 b	52.75 bc
5+7	1.01 c	2.25 f	2.25 f	23.33 a	97.58 a	46.71 c	51.43 cd

[X]Mean separation was performed by using Tukey's HSD test. Means (n= 3) followed by same letters within a column are not significantly different at $p<0.05$.

The fungal decay occurred at very low degree only at the end of 5 month (6.67%) during storage and it was seen in the ImPBTW + SMBS treatment. During the shelf life conditions, it was seen at the end of 4th and 5th month (2.50% and 23.33% respectively). No fungal deterioration was detected in the MAPTW treatment. But, fungal deterioration between treatments during shelf life was the highest in the ImPBTW (11.67%) treatment (Table 1). It has been reported by other researchers that stored carrots may become rotten and rot may develop within 1 to 3 months [2, 28]. No physiological deterioration was detected in any treatment during storage and shelf life conditions (Data not shown).

As the storage period of the carrots got longer, the carrot firmness, which initially averaged 99.67 N showed some increases and decreases; at the end of the 5th month, it decreased to 82.89 N. However, the variations between treatments were found as statistically insignificant at carrot firmness during storage time. There was no difference between the storage time at carrot firmness during shelf life conditions. The treatment of MAPTW+ SMBS treatment during shelf life resulted in the highest carrot firmness (Table 1). Similar results on carrot firmness were observed in many studies [3, 4, 24]. On the other hand, unlike our findings, Klaiber et al. (2004) [29] observed an increase in the firmness of storage resulting from the dehydration and the onset of lignification during storage.

Based on the evaluation of the color data, 'Nanco F1' variety carrots had slight reduced brightness after from 3th month during storage. Among the treatments, there was an increase in MAPTW and MAPTW+ SMBS treatments while the other treatments reduced L* value of carrot color. The MAP treatments increased the brightness of carrots. During the shelf life study, carrots had similarly reduced brightness. L* value of carrot color between treatments were the lowest in the ImPBTW + SMBS treatment during shelf life conditions (Table 1). The carrot color h° values increased as the storage period of carrots prolonged, which was initially 52.08° at the beginning and was found to be increased to 56.34° at the end of the 5th months. The carrot color h° values of SMBS treatments during storage was the highest in the treatments. As the shelf life prolonged, the carrot color h° values increased compared to baseline. The carrot color h° values of MAP treatments during storage was the highest between treatments (Table 1). Similar to our findings, it was reported by Karaca et al. (2008) [27] that carrot color L* values decreased during storage. Unlike our findings, the carrot color h° value of the carrots reduced in the MAP storage [3, 4, 27]. In a study conducted by Sulaeman et al. (2003) [30], L* and h° values in carrot chips stored at 0-1 °C for 5 months did not change.

As the storage period of 'Nanco F1' variety carrots was prolonged, the ratios of rooting and sprouting increased from 2nd month and reached to average 64.17% and 20.42% respectively at the end of 5th month. No rooting and sprouting occurred in the first 3 months during shelf life conditions and reached to the maximum values at the end of 5th months (26.25% and 48.75% respectively). The highest ratio of rooting during storage and shelf life conditions was in ImPBTW + SMBS treatment, whereas the highest ratio of sprouting occurred in ImPBTW treatments during storage and ImPBTW + SMBS during shelf life conditions (Figure 2). The ratios of rooting and sprouting of MAP treatments during storage and shelf life conditions were the lowest between the treatments. The changes in the degrees of rooting and sprouting were similar to the ratios of rooting and sprouting during storage and shelf life conditions (Table 2). The effect of SMBS treatments on the ratio of rooting and sprouting was ordinary. It was also reported by various investigators that root and sprout ratios increased during storage [3, 4, 23, 24, 26]. It was reported that the storage temperature should be between 0 and 1 °C in order to minimize the sprout rate during storage and the sprouting may develop within 1 to 3 months when stored at 5 to 10 °C [28]. In all of our treatments, rooting and sprouting were observed, but unlike our findings, in a study conducted by Terzioğlu (2000) [25], carrots were not rooted and sprouted in all treatments during cold storage for 5 months.

Figure 2. Rooting and sprouting occurred in ImPBTW + SMBS treatment (top) and ImPBTW treatment (bottom) at the end of 5th month during storage

As the storage and shelf life period of the carrots got longer, the TA content decreased. There was statistically no difference between the treatments in TA content values during storage. The highest TA content during the shelf life conditions was determined in MAPTW and ImPBTW treatments (Table 2). Unlike our findings, Genç et al. (2018a, b) [3, 4] reported that the differences in storage and shelf life periods and the effects of TA content were statistically insignificant.

During storage conditions, it was observed that the pH values of the carrots increased. The highest pH value during storage was determined in MAPTW and MAPTW+ SMBS treatments. The differences between the treatments in TA were statistically insignificant in shelf life periods (Table 2). In a study conducted on baby carrots, the pH-value increased during storage similar to our findings [27]. Genç et al. (2018a, b) [3, 4] reported similar results in which the highest pH value during storage was determined in MAP treatments. Unlike our findings, Koca (2006) [31] reported that the pH value of carrots decreased at the end of storage in stored carrots.

Table 2. Effects of treatments on rooting and sprouting ratio, rooting and sprouting degree, TA, pH value and TSS in 'Nanco F1' type carrots during 5 months of storage at 0 °C and 7 days of shelf life at 20 °C

Storage type	Rooting ratio (%)	Sprouting ratio (%)	Rooting degree (0-5)	Sprouting degree (0-5)	TA (%)	pH value	TSS (%)
Cold storage treatments							
ImPBTW	23.06 b[x]	14.44 a	0.55 b	0.27 a	0.11 a	6.18 b	9.63 b
MAPTW	14.17 c	6.11 bc	0.52 b	0.17 b	0.11 a	6.40 a	10.13 a
ImPBTW + SMBS	25.00 a	8.33 b	0.70 a	0.15 b	0.11 a	6.12 b	9.33 c
MAPTW+ SMBS	15.00 c	3.89 c	0.49 b	0.18 b	0.10 a	6.35 a	9.73 b
Storage time (Months)							
0	---	---	0.00 d	0.00 d	0.18 a	6.03 d	8.40 d
1	0.00 e	0.00 e	0.00 d	0.00 d	0.13 b	6.18 cd	8.83 c
2	3.75 d	3.75 d	0.04 cd	0.04 d	0.11 bc	6.24 bc	10.09 b
3	9.17 c	8.33 c	0.12 c	0.17 c	0.09 cd	6.28 bc	10.11 b
4	38.75 b	16.67 b	1.10 b	0.39 b	0.07 de	6.48 a	10.25 b
5	64.17 a	20.42 a	2.14 a	0.55 a	0.06 e	6.38 ab	10.56 a
Shelf life treatments							
ImPBTW	0.00 c	5.00 d	0.00 d	0.16 b	0.12 ab	5.83 a	9.18 b
MAPTW	5.33 b	9.17 c	0.12 c	0.17 b	0.13 a	6.10 a	10.03 a
ImPBTW + SMBS	23.89 a	22.78 a	0.68 a	0.62 a	0.11 b	6.10 a	8.97 c
MAPTW+ SMBS	6.81 b	13.61 b	0.38 b	0.50 a	0.11 b	6.18 a	9.23 b
Shelf life time (Months+days)							
0+7	0.00 c	0.00 d	0.00 d	0.00 c	0.14 a	6.04 a	9.00 d
1+7	0.00 c	0.00 d	0.00 d	0.00 c	0.11 bc	6.15 a	9.01 d
2+7	0.00 c	0.00 d	0.00 d	0.00 c	0.12 b	6.15 a	9.40 c
3+7	15.83 b	9.17 c	0.33 c	0.13 c	0.12 b	6.13 a	9.85 a
4+7	15.42 b	17.92 b	0.57 b	0.55 b	0.11 bc	6.16 a	9.57 b
5+7	26.25 a	48.75 a	0.88 a	1.49 a	0.10 c	5.69 a	9.29 c

[X]Mean separation was performed by using Tukey's HSD test. Means (n= 3) followed by same letters within a column are not significantly different at $p<0.05$

The TSS content during storage and shelf life period, which was initially 8.40% and 9.00% respectively at the beginning of the 'Nanco F1' variety carrots, was found to be increased and it was 10.56% and 9.29% respectively at the end of the 5th months. Among the treatments during storage and shelf life period, TSS was found to be the lowest in the ImPBTW + SMBS treatment, while it was highest in the MAPTW treatment (Table 2). It has been reported that the increase in TSS content may be due to an increase in the metabolic activity of starch to sugars (Cemeroğlu et al., 2001) [32]. Similar to our findings Genç et al. (2018a, b) [3, 4], Kasım (1994) [23], Kasım (2001a, b) [24, 26] and Karaca et al. (2008) [27] reported that TSS content increased during storage. Unlike our findings, Koca (2006) [31] and Svanberg and Nyman (1997) [33] found a decrease in TSS in stored carrots.

4. Conclusions

According to the findings, weight loss in imperforated bag was higher than MAP treatments during storage. There was no difference between washing with tab water and SMBS in terms of weight loss. For carrots that are packaged in MAPTW+ SMBS and MAPTW treatments, there was an increase in L* values in color and the appearance was preserved, and the ratio of rooting and sprouting was lower. It was determined that ImPBTW and ImPBTW + SMBS treatments of ‘Nanco F1’ type carrots could be kept at 0 °C and 85-90% relative humidity for 3 months without any quality deterioration. It was also determined that MAPTW+ SMBS treated ‘Nanco F1’ type carrots could be stored for 4 months and MAPTW treatment of ‘Nanco F1’ type carrots could be stored for 5 months at 0 °C and 85-90% relative humidity without losing much of the quality for local and distant markets (Figure 3). In addition, it was found that SMBS treatments were not sufficient to prevent rooting and sprouting, while in order to reduce the weight loss of carrots, MAP treatment was necessary.

Figure 3. Treatments at the end of 5th month during storage

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6. References

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