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Effect of Controlled and Modified Atmosphere on Storage Quality of Cauliflower (*Brassica oleracea* L. var. *botrytis* cv. Iglo) Heads

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Abstract: Cauliflower (*Brassica oleracea* L., var. *botrytis* cv Iglo) heads with jacked leaves were stored in air, in PE bags (perforated and nonperforated), in PVC wrapped and in CA (3% O_2 + 3% CO_2) at 1°C and 90 – 95% RH for 60 days. Shelf life was tested after 3 days at 20°C. Changes in chemical composition and external quality of heads were determined during storage. Increase in SS, losses of acidity and ascorbic acid of air stored heads were higher than those stored in CA or MA. The carbohydrate content of heads was slightly higher in CA and MA. The decomposition of carbohydrates slowed down in CA or MA storage. The better external quality was obtained from those stored in CA or in PVC wrapped during storage and shelf life. From these findings it was concluded that cauliflower heads can be held for 3 weeks in air or PE bags and storage life can be extended up to 6 weeks by CA or PVC wrapped applications.

Keywords: Cauliflower (*Brassica oleracea* L., var. *botrytis*), normal atmosphere, controlled atmosphere and modified atmosphere packaging storage, quality.

Iglo Karnabahar Çeşidinin Normal ve Kontrollü Atmosfer Koşullarında Depolanmasının Kaliteye Etkileri

Özet: Bu çalışmada Iglo çeşidine ait brakte yaprakları kesilmemiş karnabaharlar, 1°C sıcaklık ve %90–95 oransal nem içeren odada normal atmosferde, delikli ve deliksiz polietilen torbalarda (MA) ve %3O_2 + %3CO_2 gaz karışımı içeren kontrollu atmosfer (KA) koşullarında 60 gün süreyle depolanmıştır. Depolama süresince 20 gün arayla kaliteye yönelik kimyasal değişimler ve her depolama sürecinden sonra 20°C sıcaklıkta 3 gün bekletilerek izlenen raf ömründe çiçeklerdeki renk değişimi, görünüş, sıkılık, beneklenme, çiçeklerde bozulma ve braktelerdeki renk değişimi dikkate alınarak görsel değerlendirme yapılmıştır. Bulgulara göre; normal atmosferde depolanan karnabaharlarda suda çözünür kuru madde miktarındaki artış, titre edilebilir asitlik ve askorbik asit miktarındaki kayıplar, MA ve KA koşullarında depolananlara göre daha yüksek bulunmuştur. Depolama süresince karbonhidratların parçalanması KA ve MA koşullarında NA'de depolanan karnabaharlara göre daha yavaş olmuştur. Depolama süresince ve depolamadan sonra 3 günlük raf ömrü sonunda görsel kalite ve ağırlık kaybı yönünden en olumlu sonuçlar KA ve PVC film kaplanarak muhafaza edilen örneklerde saptanmıştır. Bulgulara göre Iglo karnabahar çeşidi NA koşullarında açıkta ve polietilen torbalar içerisinde 3 hafta kadar depolanırken, KA ve PVC film kaplanarak depolama süresinin 6 haftaya kadar uzatılabileceği tespit edilmiştir.

Anahtar kelimeler: Karnabahar (*Brassica oleracea* L., var. *botrytis*) normal, modifiye ve kontrollü atmosferde depolama, kalite

1. Introduction

Cauliflower is not usually kept in cold storage conditions in Turkey. However, an overspill can be stored for a short time to await a more favorable market. In earlier experiments cauliflower heads can be satisfactorily held for 3 or 4 weeks at 1°C and 90% RH if they are in good condition. A high RH of at least 95% is desirable to prevent wilting. Slightly immature, compact heads keep better than more mature ones (Kaynaş et al., 1994).

Several review articles have been published on physiological and biochemical effects of CA and MA on vegetable crops including cauliflowers

(Lipton, 1977; Isenberg, 1979; Weichmann, 1986; Kader, 1986; Leshuk and Saltveit, 1990; Wang, 1990). Early studies suggested that a gas concentration of 10% CO_2 + 11% O_2, increased the storage life of cauliflower by about 2 weeks at 0°C (Smith, 1952) and later findings however showed that the storage life was not extended by either low O_2 or high CO_2 and cauliflower curds were injured by low O_2 (2% or less) or by high CO_2 (5% or more). Overall conclusion is that favorable effects of CA is obtained by 3–5% CO_2 and 3% O_2 (Lipton et al., 1967; Lipton and Harris, 1976; Adamicki and Kepka, 1977; Amariutei et al.,1977). Therefore, there are definite advantages of CA on storage of cauliflowers by up to 8 weeks within these limits and no damage of CA occurs to the curds and the attached green tissues are greatly benefited.

In cauliflower, storage in 1% O_2 or less resulted in off–odors and off–flavor, but the latter was noticeable only after the heads were cooked (Lipton and Harris, 1976). An off–flavor following cooking was also found after storage in 15% CO_2. However, when the crop was aerated sufficiently before cooking, the taste was found to be normal. No discoloration was observed on raw heads after CA storage. A greyish–yellow color developed on heads which were cooked immediately after high CO_2 storage. Higher CO_2, concentrations resulted in a darker color but the discoloration of heads was reversible after exposing to air for 24 hours (Lipton et al., 1967).

Adamicki and Kepka (1977) also found similar results after storage in 5% CO_2 and 5% O_2 or in sealed PE bags. Cauliflower stored either in 1–6% O_2 or in air had identical textures, but increased CO_2 (10%) resulted in softening of cooked tissue. Shipway (1974) stored precooled cauliflowers for 7 days at 1°C and plus 4 days at 18°C in perforated and non-perforated PE and in four types of shrink film with different permeability characteristics. CO_2 remained below 1% during 1°C storage in all but the PE packages. After an additional 4 days in 18°C, CO_2 reached 3% in one of the shrink–wrapped packages, the highest concentration found in all treatments. The cauliflower stored in sealed PE showed high CO_2 injury. They stored cauliflower at 1°C and 5°C in air, 3–5% O_2 + 2.5–3.5 % CO_2 and in sealed PE bags and found that less weight loss occurred in CA than in air. No significant differences were observed among CA treatments. Heads stored in CA remained whiter and firmer than those stored in air. The lowest weight loss was observed in heads stored in the PE bags than those stored in air or CA. Isenberg (1979) showed that data from stored cauliflowers in different CA conditions indicated only a few statistically significant, but not commercially important, benefits in weight losses from use of CA.

Few literature is available on postharvest changes in chemical composition of cauliflower curds. Dry matter content of the curds slightly increased during storage at 0°C or 4°C. That was attributed to the translocation of breakdown products from the leaves in to the curd. In heads without leaves a linear decline in dry matter content was noted (Böttcher, 1986). Vitamin C contents of curds declined and titratable acid content of the curds increased during storage at 0°C or 4°C (Böttcher, 1987). Watada (1987) observed 10% loss of ascorbic acid in cauliflower stored for 2 weeks at 0°C, and 50% in those stored for 2 weeks at 20°C. Mertens and Tranggono (1989) noticed that total sugar content was marginally higher and external quality of the heads was sometimes slightly better in CA storage. They concluded that storage of cauliflower heads in 5% CO_2 + 3% O_2 had a very small effect, if any, on respiration and ethylene metabolism of the curd, but a definite effect on both metabolisms of the leaf parts was quite clear. Olarte et al. (2009) observed minimally processed cauliflower packaged in four different film types have the difference physiological response during storage. They suggested P-Plus 120 film due to its high permeability the most suitable for preserving its sensory qualities of cauliflower.

Cauliflower curds packed in individual HDPE bags could retain white colour, good sensory quality, firm and fresh curds with least weight loss, texture and minimum spoilage up to 21 days storage at low temperature (0 ± 1^0C, 90-95% RH) condition (Dhall et al.,2009). They suggested cauliflower heads without washing followed by packing in HDPE bags and cold storage for extending the marketability.

The main postharvest problems of cauliflower heads are yellowing of the jacked leaves and browning of the curd, compactness, to get bitter which decrease storage and shelf life and affect consumer behavior (Hodges et al., 2006; Licciardello et al., 2013; Zhan et al., 2014). Alibaş and Köksal (2015), observed that vacuum precooling was found to be most suitable method before cauliflower was submitted to cold storage (either CA or room condition) and sent to market directly. Furthermore, quality parameters more decreased the storage of cauliflower heads without precooling.

This study deals with the effects of different storage treatments on changes in chemical composition and external quality of cauliflower heads during storage.

2. Materials and Methods

Cauliflower (*Brassica olerecea* L., botrytis group) were harvested when the heads reached about 150–200 mm diameter from experimental field of Yalova – Atatürk Central Horticultural Research Institute in January. Cauliflower heads with jacked leaves were stored for 20, 40, and 60 days at 1°C and 90–95% RH.

The following storage treatments were used in this experiment: NA: Nonwrapped (in air), MA–1: Non–perforated PE bags (30 µm), MA–2: Perforated PE bags (5 mm diam. holes per kg head), MA–3: PVC wrapped (15 µm, with a permeability of 200 g water vapour/m^2/day, 12.000 ml O_2/m^2/day.atm.), CA: 3 % O_2 + 3 % CO_2

Gas composition analyses of the internal atmosphere were not made on passive MA (MA–1, MA–2, MA–3). The appropriate atmosphere composition was derived by continuously mixing N_2, CO_2 and air in modified flow–through system as originally described by Claypool and Keefer (1942).

Each treatment was replicated three times, including three heads in each treatment. Some characteristics of curds were determined at harvest time, 20, 40, and 60 days after storage. The characteristics considered were as follows: Soluble solids (SS), titratable acidity (I.F.J.U. No.3), ascorbic acid (I.F.J.U. No.17), invert sugars (Rose, 1958), total sugar (I.F.J.U. No.4), starch content (Dimler at al.,1952), weight loss (%). Respiration rate was measured at 20°C following harvest. After each storage period and shelf life (3 days at 20°C transferred) external quality assessments of cauliflowers were also conducted according to 1–5 scale (5:excellent.. 3: acceptable.. 1: very poor) and was based on overall visual external quality attributes such as; colour, appearance, compactness, spotting, bruising of curds, freshness and colour of outer leaves.

Statistical analyses of variance were at 99 and 95% levels. For the significant differences means were separated by Duncan's Multiple Range Test at 5% level.

3. Results and Discussion

The effects of different storage treatments and storage periods on changes of some characteristics in cauliflower curds are summarized in Table 1. SS of cauliflower curds stored in CA and MA were lower than in air storage. After 20, 40, and 60 days the heads in air had a higher SS than heads stored in CA and MA storage. SS increased during first 20 days in cold storage except in CA; the increase of SS in air was even more substantial, and slight differences were observed among MA package types.

Table 1. The effect of different storage treatments and storage periods on changes of some characteristics in cauliflowers "cv. Iglo", at 1°C.
Tablo 1. *Farklı depolama uygulamalarının Iglo karnabahar çeşidinin bazı kalite özelliklerindeki değişimine etkisi (1°C)*

Storage Treatments	Soluble Solids (%)				Acidity (% malic acid)				Ascorbic acid (mg 100 g^{-1})			
	0	20 Days	40 Days	60 Days	0	20 Days	40 Days	60 Days	0	20 Days	40 Days	60 Days
NA**	5.83	6,33 a*	6,86 a	10,66 a	0,168	0,134 e	0,136	0,112	75,4	63,0 b	12,8 d	3,8 d
MA-1	5.83	5,90 bc	5,86 b	5,83 c	0,168	0,147 c	0,121	0,119	75,4	66,0 a	31,9 c	26,9 c
MA-2	5.83	5,93 bc	5,90 b	5,80 c	0,168	0,141 d	0,129	0,114	75,4	67,4 a	33,7 c	27,5 c
MA-3	5.83	6,00 b	5,87 b	5,80 c	0,168	0,154 b	0,151	0,127	75,4	67,4 a	44,4 b	36,2 b
CA	5.83	5,83 c	5,83 b	6,03 a	0,168	0,183 a	0,163	0,127	75,4	68,6 a	60,3 a	43,8 a

Storage Treatments	Invert Sugars (% g)				Total Sugars (% g)				Starch (% g)			
	0	20 Days	40 Days	60 Days	0	20 Days	40 Days	60 Days	0	20 Days	40 Days	60 Days
NA	2,26	1,62 b	1,46 c	1,20 c	4,00	3,56 b	2,36 c	2,06 d	5,33	3,68	3,68	0,35
MA-1	2,26	1,58 b	1,28 d	1,14 d	4,00	3,50 b	2,97 a	2,45 b	5,33	4,75	2,66	0,52
MA-2	2,26	1,39 c	1,58 b	1,26 b	4,00	3,01 c	3,01 a	2,26 c	5,33	5,90	3,83	1,65
MA-3	2,26	1,28 d	1,06 e	1,06 e	4,00	2,83 c	2,68 b	2,13 cd	5,33	5,41	3,75	1,58
CA	2,26	2,09 a	1,85 a	1,74 a	4,00	4,32 a	3,24 a	3,04 a	5,33	5,10	3,81	1,79

*Mean separation in columns by Duncan's Multiple Range Test, 5% level
**NA: Non wrapped (air); MA-1: Non perforated PE; MA-2: Perforated PE; MA-3: PVC wrapped; CA: 3 %O_2 + 3 %CO_2

The increase in SS during 40 or 60 days in air was more pronounced in CA and in MA storage because of a higher weight loss in air. Increase in dry matter content during storage was explained by Böttcher (1986) as the translocation of breakdown products from the leaves into the curd.

The comparison between storage treatments showed clear differences in titratable acidity after 20 days of storage. The decrease in titratable acidity was less in CA and in PVC wrapped than that in PE bags or in air. After 20 days differences between storage treatments were not statistically significant, but the curds had slightly more acid in CA and PVC wrapped storage. Loss of organic acids in CA or MA was attributed to an increase in CO_2 fixation, an inhibition of the respiratory metabolism, and a lower consumption of the acid under CA or MA (Wang, 1990).

During storage ascorbic acid contents decreased in all treatments. Decrease in ascorbic acid in air was more rapid than other treatments during the first 20 days of storage. The losses of ascorbic acid in curds after 60 days of storage were 94. 0%, 64.3%, 64.3%, 51.9% and 41.9% for air, MA–1, MA–2, MA–3, and CA, respectively. These observations are in parallel with those reported by others (Böttcher, 1987; Watada, 1987). It was concluded that low O_2 and high CO_2 concentration inhibited losses in ascorbic acid content.

Invert and total sugar decreased during storage but a more substantial decrease was seen in NA and in MA packages. On the other hand, CA storage reduced the decrease of sugar content. After 60 days of storage in CA and in MA total sugar contents of curds were significantly higher than in air. Overall total sugar losses after 60 days of storage at 1°C were 48.5%, 38.8%, 43.5%, 33.0% and 24.0% for air, MA–1, MA–2, MA–3 and CA respectively. Storage treatments showed no significant differences in starch content of curds, but in the heads stored in CA and MA the decomposition of starch was inhibited. Isenberg (1979) reported a linear relation (r= 0.88) between CO_2 concentration of the atmosphere and rate of decomposition of sugars in cauliflower. Our data indicate that the carbohydrate content of stored heads is in dynamic state where carbohydrates, the most important substrate for respiratory metabolism of the heads, are being continuously metabolized. Mertens and Tranggono (1989) found that total sugar content in cauliflower decreased during cold storage but a more substantial decrease was seen in shelf life. Decrease in sugar content in NA was also more than those stored in CA.

Cauliflowers stored for 20 days at 1°C gave a weight loss of 16.7% when held in air (nonwrapped) and the weight loss dropped by about 1.4%, 1.5%, 2.2% and 1.5% when held in MA–1, MA–2, MA–3 and CA respectively (Figure 1). Similar results were obtained after 40 or 60 days of storage. There were significant differences in weight loss between NA and CA or MA in all storage periods. MA and CA are therefore commercially important in reducing the weight loss of cauliflower. In contrast Isenberg (1979) concluded that no commercial important benefits were observable in weight losses from the use of CA. However, results reported by Adamicki and Kepka (1977) on the weight loss of cauliflower in air, in MA and in CA showed similar trends as we found in our studies. They observed significant differences between CA and MA, but no differences were found among MA and CA treatments themselves.

Respiration rate of cauliflower heads at 20°C after harvest is given in Figure 2. CO_2 production by heads was about 84 mg/kg–h in the first day and then slightly decreased. After three days the production remained at a nearly constant level. After ten days the respiration rate showed a rapid increase. This was probably due to senescence associated with physiological breakdown.

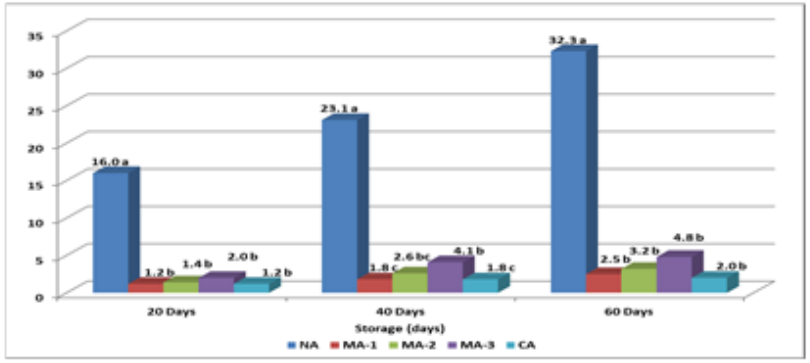

Figure 1. The effect of different storage treatments and storage periods on weight loss of cauliflower heads.

Şekil 1. *Iglo karnabahar çeşidinde farklı muhafaza uygulamalarının farklı depolama sürelerinde ağırlık kaybına etkisi*

*Mean seperation within each period was conducted by Duncan's multiple Range Test at 5% level

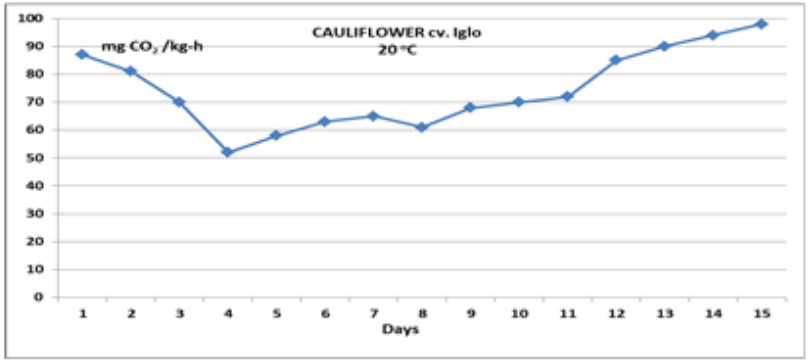

Figure 2. Changes in respiration rate of cauliflower heads after harvest at 20^{0}C

Şekil 2. *Iglo karnabhar çeşidinin hasattan sonra 20°C'de solunum hızındaki değişimleri*

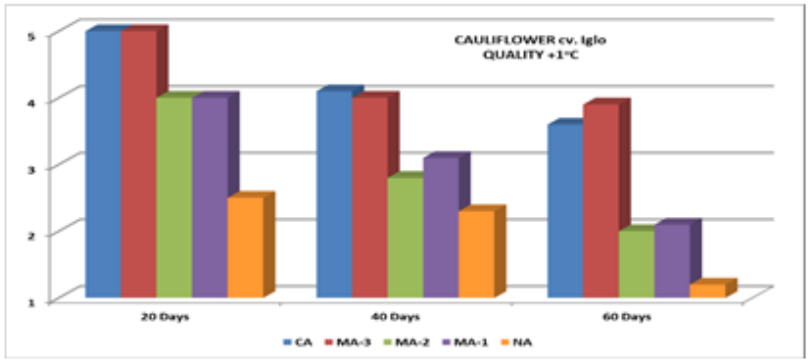

Figure 3. External quality scores of cauliflower heads during storage periods.

Şekil 3. *Iglo karnabahar çeşidinde depolama süresince dış kalite özellikleri*

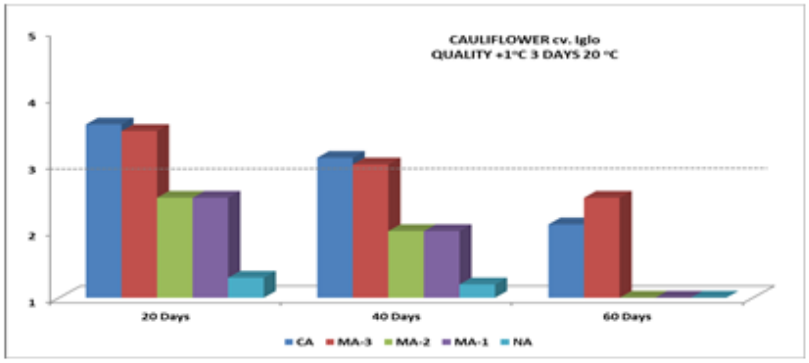

Figure 4. External quality scores of cauliflower heads during shelf life (3 days at 20^{0}C)storage periods.

Şekil 4. Iglo karnabahr çeşidinde depolama dönemleri sonunda *raf ömrü(20°C'de 3 gün) süresince dış kalite özellikleri*

*5: excellent ……..3: acceptable……..1: very poor

Differences in external quality between storage treatments were found to be visually important (Figure 3). The heads were acceptable for their general appearance after 20 days of storage in CA or MA. The quality in CA and in PVC wrapped treatments was slightly better than PE bags and in air. The quality loss was although rapid in all treatments after 3 days of shelf life at 20°C, the heads stored in CA and in PVC wrapped were still acceptable (Figure 4). After 40 and 60 days of storage the quality of heads stored in air and PE bags was unacceptable even prior to the transfer to 20°C. It appears that 40 days of storage either in CA or PVC wrapped is the limit for quality acceptance if a 3 days market margin is allowed. CA and PVC wrapped heads were found to be brighter, more compact and cream in color compared to those in PE bags and NA treatments. Cauliflowers stored in air and in PE bags showed greyish – yellow color, pitting on curds, and were excessively soft and had strong off–odors and flavors. No yellowing and abscission of outer leaves were observed in CA and in PVC wrapped.

4. Conclusion

Based on our studies, application of MA and CA are the most effective methods compared to NA in retarding the senescence of cauliflower heads. CA and MA have an inhibitory effect on the overall metabolic system of stored cauliflowers. It is generally considered that a slower rate of utilization of carbohydrates, organic acids, and other substrates leads to prolonging the life of heads. In our experiments cauliflower heads did not show favorable results in external quality from storage in PE bags. This is also true during the shelf life. The higher CO_2 and RH inside the PE package have been harmful to the longevity of the heads. PVC and CA have considerable importance in preserving the postharvest quality and extending the shelf life of cauliflower heads. The results of our studies described in this paper showed that PVC and CA can almost double the storage of cauliflower heads followed by a reasonable period of marketing at elevated temperatures. 6 weeks of storage at 1°C with 3 days at 20°C is the upper limit that can be obtained by using CA (3% O_2 + 3% CO_2) or PVC wrapping, which is otherwise 3 weeks with air and PE. Since CA is not practical and commercially available in Turkey strong emphasis will be exerted on using the stretch films to provide MA conditions in extending the shelf life of cauliflower along with the decrease in concomitants in postharvest losses in Turkey.

References

Adamicki F and Kepka AK (1977). Storage of cauliflower in CA and plastic bags. Acta Horticulturae, 62:23-29.

Alibaş İ and Köksal N (2015. Karnabaharın Basınçlı hava, vakum ve hidro önsoğutması (Brassica oleracea L. var. Botrytis cv. Freemont): Bölüm I. Önsoğutma parametrelerinin belirlenmesi. Ciencia e Tecnologia de Alimentos, 34(4):730-737.

Amariutei A, Tataru DP and Tasca G (1977). Research results on refrigerated and CA storage of cauliflower, *Brassisca oleracea* L.var, *botrytis*. Acta Horticulturae, 62:31-39.

Böttcher H (1986). Changes in the dry matter and saccharides of of cauliflower (*Brassica oleracea* var. *botrytis* L.) during storage. Gartenbau, 34(8): 409-422.

Böttcher H (1987). Changes in the total vitamin C and total acid contents of cauliflower (*Brassica oleracea* var. *botrytis* L.) during storage. Gartenbau, 35(1): 33-45.

Claypool CC and Keefer RM (1942). A colorimetric method for CO_2 determination in respiration studies. Proc. Amer. Soc. Hort. Sci., 40:177-186.

Dhall RK, Sharma SR and Mahajan BVC (2009). Effect of packaging on storage life and quality of cauliflower stored at low temperature. J. Food. Sci. Technol., 47(1):132-135.

Dimler RJ, Schaeffer WC, Wise CS and Rist CE (1952). Quantative paper chromatography of D-glucose and its oligosaccharides. Anal. Chem., 24: 1411-1414.

Hodges DM, Munro KD, Forney CF and McRae KB, (2006). Glucosinolate and free sugar content in cauliflower during controlled –atmosphere storage. Postharvest Biology and Technology, 40(2): 123-132.

Isenberg FMR (1979). Controlled atmosphere storage of vegetables. Horticultural Review, 1:337-394.

Kader AA (1986). Biochemical and physiological basis for effects of controlled and modified atmospheres on fruit and vegetables. Food Technol., 40:99-100.

Kaynaş K, Özelkök İS and Sürmeli N (1994). Controlled atmosphere storage and modifıed atmosphere packaging of cauliflower. New Application of refrigeration of the fruit and Vegetables Processing Sym., Proc. 75-84. TÜBİTAK - IIR, Istanbul, Turkey.

Leshuk JA and Saltveit ME (1990). Controlled atmosphere storage requirements and recommodations for vegetables. In: Food Preservation by Modified Atmosphere, 315-352.

Licciardello F, Muratore G, Spagna G, Branca F, Ragusa L, Caggia C, Randozza C and Restuccia C (2013). Evaluation of some quality parameters of minimally processed white and violed-pigmented cauliflower curds. Acta Horticulturae 1005: 301-308.

Lipton WC (1977) Recommendations for CA storage of Broccoli. Brussel sprouts, Cabbage, Cauliflower, Asparagus and Potatoes. Proc. 2nd Nat. CA Res. Conf. Michigan State Univ., 277-281.

Lipton WC and Harris CM, (1976). Response of stored cauliflower (*Brassica oleracea* L., *botrytis* group) to low O_2 atmospheres. J. Amer. Soc. Hort. Sci., 101(3): 208-211.

Lipton WC, Harris CM and Couey HM, (1967). Culinary quality of cauliflower stored in CO_2 enriched atmospheres. Amer. Soc. Hort. Sci., 91: 852-859.

Mertens H and Tranggono M, (1989). Ethylene and respiratory metabolism of cauliflower (*Brassica oleracea* L. convar. *botrytis*) in controlled atmosphere storage. Acta Horticulturae, 258: 493-501.

Olarte C, Sanz S, Echavarri F and Fernando A, (2009). Effect of plastic permeabilty and exposure to light during storage on the quality of minimally processed broccoli and cauliflower. LWT- Food Science and Technology, 42(1): 402-411.

Rose FA (1958) Dinitrophenol method for reducing sugar. In: Potato Processing, by The AVI Publishing, 469-470.

Shipway MR (1974). Short-term storage of cauliflower in film wraps. Acta Horticulturae, 38: 47-51.

Smith WH (1952) The commercial storage of vegetables. Dept. Sci. Ind. Res. Leaflet No.15, London 8p.

Wang CY (1990). Phsiological and biochemical effects of controlled atmosphere on fruits and vegetables. In: Food Preservation by Modified Atmosphere, 197-223.

Watada AE (1987). Vitamins. In: Postharvest Physiology of Vegetables, 455-468.

Weichmann J (1986). The effect of controlled atmosphere storage on the sensory and nutrional quality of fruits and vegetables. Horticultural Review, 8: 101-127.

Zhan L, Pang L, Li Y and Shao J (2014). Light exposure reduced browning enzyme activity and accumulated total phenols in cauliflower heads during cool storage. Postharvest Biology and Technology, 88: 17-20.