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Summer storage of cabbage

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ABSTRACT

Cabbage production is problematic in hot climates, since it grows best in a temperature range of 16–18 °C. In Israel the best production time is fall and winter, but to allow for year round supply cultivation and storage is necessary in the spring and summer months. Three cabbage cultivars, Cheers, Fresco and Pruktor, were examined for their ability to be grown in the spring and stored over the summer. Experiments were conducted over four seasons. Storage was in both regular air and controlled atmosphere at 1 °C, for up to 120 d. Controlled atmosphere was applied by two methods; an experimental system of containers of 400 L, and in a small commercial room of 5 MT. Regular air storage for an extended period was not suitable because all the cultivars developed unacceptable weight loss, yellowing, decay and physiological disorders (black spot and grey rib) when stored for more than one month. CA enabled storage of Cheers and Pruktor for up to three months. Fresco developed high levels of black spot under both regular and controlled atmosphere storage. Cheers had higher levels of isothiocyanates and less physiological disorders than Pruktor. Cheers was found to be the best cabbage cultivar for spring production and storage over the summer. The CA conditions of 2% O_2 and 5% CO_2 were better than 3% O_2, 6% CO_2.

1. Introduction

Cabbage (*Brassica oleracea*) is known as a cool climate crop. It is best grown in temperate areas of the globe and can be stored for long periods when harvested in the fall. Maynard and Hochmuth (1997) found that 16–18 °C was the optimum temperature range for cabbage growth. Development may be slow and abnormal, and the quality is often poor, when the mean monthly temperatures exceed 21 °C. Israel has a climate with a wet, mild winter and a hot dry summer. The best period for growing cabbage is therefore in the fall and winter. Cabbage grown at this time can be stored for number of months, while cabbage heads grown in the spring and summer have much shorter storage life.

In storage, cabbage is prone to postharvest weight loss and shriveling, yellowing and fungal infections *(Botrytis cinerea, Alternaria spp, Mycosphaerella brassicicola, Fusarium roseum, Sclerotinia sclerotiorum),* and bacterial infections *(Pseudomonas marginalis, Erwinia carotovora)* (Adair, 1971; Geeson, 1983). Among these pathogens, *B. cinerea* is the prevalent fungus which causes the worst damage to cabbages in storage. A major physiological storage disorder is black spot. This disorder is also called pepper-spotting, grey speck and black speck (Strandberg et al., 1969; Walsh et al., 1983). The damage caused by black spot and *B. cinerea* can be reduced using controlled atmosphere (CA). CA (2–3% 0_2, and 5–6% CO_2) storage can extend cabbage storage life, delay yellowing and maintain good quality characteristics (Geeson and Browne, 1980; Berard et al., 1985; Prange and Lidster, 1991). Low concentrations of O_2 (1%) at 0 °C have proved to be effective in delaying yellowing and in reducing the incidence of decay in Chinese cabbage (Wang, 1983). High levels of CO_2 (> 6%) may cause off odors and flavors, while levels below 1.5% O_2 may induce fermentation (Menniti et al., 1997).

There are many different cultivars of cabbage that have been developed for both fresh consumption and for processing. Some have better yields when grown in hot weather than others (Greenland et al., 2000). The growing season will affect many quality parameters of the cabbage including head size density, ratio of protein to fiber, and concentration of glucosinolates (Kleinhenz and Wszelaki, 2003; Radovich et al., 2005; Taniwaki et al., 2009). There are also differences among cultivars with regard to storage potential. Cabbages are commonly stored at low temperature, and while this retards the loss of quality, it does not fully stop senescence. Cabbage quality gradually declines during low temperature storage because of disease, water loss, and biochemical changes (Suojala, 2003).

In Israel, the most commonly cultivated cabbage is Pruktor, which is grown both in the fall and the spring. However, its storage potential is

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lower in the spring season. Two other cultivars, Cheers and Fresco, have been introduced which may be better suited for spring planting and summer storage. The purpose of this research was to examine 1) which cabbage cultivar is better suited for spring and summer production; 2) what are the best conditions for storage of the crop and how long can it be stored; 3) what changes to the vegetable quality occur during the storage.

2. Methods and materials

2.1. Cultivation and storage

Three F1 hybrid cultivars, Pruktor, Cheers and Fresco, were planted in open fields at the beginning of April and harvested in June when the heads reached 1.5 kg. Experiments were conducted over four seasons.

Storage temperature was 1 °C ± 0.5. The relative humidity was over 95% as determined by model HL20 + 21 HydroLog (Rotronic AG, Switzerland). There were two methods of controlled atmosphere (CA) storage. The first was in an experimental CA storage system (International Controlled Atmosphere (ICA), Paddock Wood, England). CA chambers of 400 l held 40 kg of cabbage heads and the gas composition was developed by flowing O_2, CO_2 and N_2 through the chambers. The system was first flushed with N_2 until the required O_2 concentration was achieved, and then CO_2 was added. Once the proper atmosphere was reached, the system assessed and corrected each hour. A paramagnetic cell was used to measure O_2, and an infra-red analyzer measured CO_2. The CA formulations varied from 2 to 5% O_2, and 0.5 to 6% CO_2 and are indicated in each trial. Each CA formulation was tested on 3 replicates of 8 cabbage heads for each cultivar. The second method was in 18 kg boxes in a 5 MT CA storage room. Each box was a replicate and there were three replicates for each treatment. The boxes were with or without a ventilated polyethylene liner of 40 µm thickness with macro perforation of 7 mm holes. The CA formulation in the commercial storage room was 2% O_2, 5% CO_2. Storage time for the different trials varied between 90 to 120 d.

2.2. Quality measurements after storage

At the end of storage, three replicates of 8 heads of cabbage from each replicate were examined for decay, weight loss and physiological disorders which included yellowing, black spot and rib greying. Decay was determined either as percentage of area with decay, or as a decay index on a scale of 1–5, with 1 being healthy and 5 being over 50% of the surface area affected. The decay was for the most part *Botrytis cinerea,* but in some cases a watery decay was present due to the development of bacterial (*Erwinia carotovora)* infection.

Weight loss was determined by weighing 8 heads at harvest and at the conclusion of storage for each treatment.

Cabbage head color was measured after removing 4 leaves from the head, in order to minimize measuring decay or mechanical injury. Yellowing was determined non-destructively by a Multiplex instrument (Force-A, France). This instrument shines light on an object with four wavelengths, and receives fluorescence from three wavelengths. The twelve signals are calculated as different indices (Bahar et al., 2012; Ghozlen et al., 2010). One index, SFR_R, is proportional to the chlorophyll content of the tissue measured, and can be a measure of loss of green color, or yellowing (Bahar et al., 2012).

Black spot and grey rib were measured on a scale of 1–5, with 1 being healthy heads. For black spot the scale was 1- no damage 2.5 - few black spots in 4 outer leaves, 3 - black spots on more than 4 outer leaves, 5- black spots throughout the head. Up until an index of 3 the heads are marketable. Grey rib develops throughout the head, and is determined after slicing the head in half. The index was 1 – no damage, 2.5 scattered grey rib in the sliced head – still marketable, 3 – greater number of grey rib – unmarketable, 5 – grey rib throughout the head.

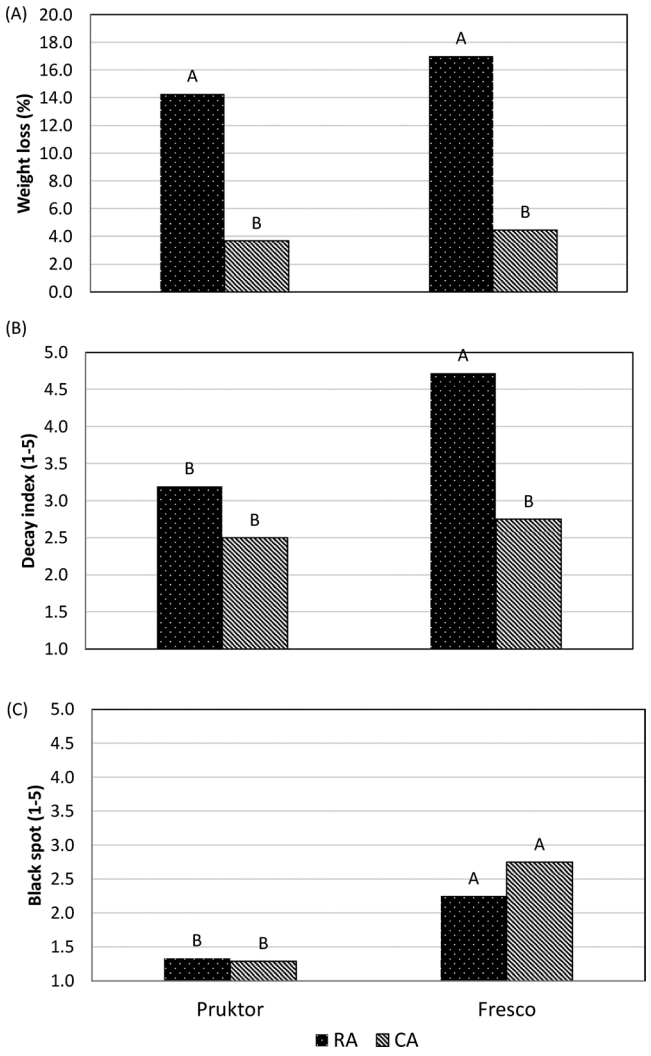

Fig. 1. Weight loss (A), decay index (B), and black spot index (C) of Pruktor and Fresco cabbage cultivars stored under regular air (RA) and controlled atmosphere (CA of 3% O_2, 6% CO_2) for 120 d at 1 °C. Letters indicate significant differences (P = 0.05) between the two cultivars under the different storage conditions.

2.3. Determination of isothiocyanates

Isothiocyanates are produced by enzymatic conversion of glucosinolates, thus an indirect method of determining glucosinolates. At each time of measurement 100 g from 3 cabbages were taken as a wedge from the outer to the inner leaves for each treatment. The samples were sliced thinly, frozen in liquid N_2, dried in a lyophilizer, and pulverized with a mortar and pestle. One hundred mg of dried material was placed in a bottle with 1 ml distilled water, mixed for 5 min at 25 °C and 20 min at 35 °C. Volatiles released were trapped by solid phase microextraction (SPME), onto a 1 cm fiber coated with 65 µm layer of polydimethylsiloxane/divinylbenzene (Supelco, Bellefonte, PA, USA).

The volatiles were desorbed for 5 min at 250 °C in the splitless inlet of an Agilent 7890 A gas chromatograph (Palo Alto, CA, USA) equipped with an HP-5 column (J&W Scientific, Folsom, CA, USA). Heating began at 50 °C to 150 °C at 6 °C/min for 5 min, and then to 250 °C with a rate increase of 100 °C/min for 2 min. Helium carrier gas flow rate was 0.8 ml min^{-1}, and the effluent was sent to an Agilent 5975C mass spectrometer detector that scanned from m/z 40 to 206 at 7.72 sans s-1 in positive ion mode. Mass spectra in electron impact mode were generated at 70 eV. Chromatographic peaks were identified by comparing the mass spectrum of each component with the National Institute of