Journal of Stored Products Research 46 (2010) 155–160

Contents lists available at ScienceDirect

Journal of Stored Products Research

journal homepage: www.elsevier.com/locate/jspr

Storage of red chili pepper under hermetically sealed or vacuum conditions for preservation of its quality and prevention of mycotoxin occurrence

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ARTICLE INFO

Article history:
Accepted 13 February 2010

Keywords:
Vacuum
Hermetic
Capsicum annuum
Quality index
Aflatoxin

ABSTRACT

The effect of storage under hermetically sealed or vacuum storage methods, compared with the traditional method, on important quality indices for Turkish red chili peppers (RCPs) was evaluated at a semi-commercial scale in a warehouse. One tonne lots of flaked and mechanically dried RCP of maximum moisture content 10 ± 1% were stored for six months under a low absolute pressure of 80–100 mm Hg, under sealed, airtight conditions, or under traditional storage conditions (bags stacked in barns; as a control). Basic quality parameters related to microbiological counts, amount of aflatoxins (B_1 and total), pungency properties, colour levels, organoleptic characters and moisture contents were determined before and after 6 months of storage. The experiments indicated that the best quality RCPs were obtained by vacuum storage with quite low losses in quality indicators (capsaicin, colour and aflatoxin). Hermetic storage conditions resulted in major losses of colour, while microbial growth and aflatoxin occurrence were inhibited, and the pungency of RCP was protected. The results supported the feasibility of commercial application of airtight and vacuum storage technologies for long-term storage of RCP. The sealed flexible vacuum–hermetic storage technology introduces substantial advantages over traditional storage methods in the preservation of quality characteristics such as colour, pungency, and aflatoxin of RCP for longer storage periods.

1. Introduction

Red pepper, *Capsicum annuum* L., is one of the oldest known edible vegetables, used by Mexican Indians long before the birth of Christ (Govindarajan, 1985). The archaeologist, R.S. Machneish, found pepper seeds dating from about 7500 BC in Mexico (Fett, 2003). It is native to America, and has spread into Asia, Europe and Africa. Turkey is the third largest producer of pepper after China and Mexico (Anonymous, 2007). Because of their vivid colouring, taste, aroma and in some cases peculiar pungency, chili peppers (*Capsicum* spp.) are widely used to modify the colour and flavour of soups, stews, sausages, cheese, snacks, salad dressing, sauces, pizzas and confectionary products, and as a food additive for colour and physiological or pharmaceutical purposes (Nieto-Sandoval et al., 1999; Topuz et al., 2009; Li et al., 2009).

Red chili pepper (RCP) is an extremely important crop for the Turkish food industry. It is mainly produced in South and West Anatolia, and in the Marmara regions of Turkey. The majority of red pepper produced in South Anatolia is processed into spices, but it is also consumed as a fresh vegetable and red pepper paste or sauce (Oztekin et al., 1999). RCPs produced in the Kahramanmaras, Gaziantep and Sanliurfa provinces of Turkey are well known for their pungent tastes and flavours.

The amount of milled and ground RCP in Kahramanmaras and surrounding areas is about 18,000 tonnes/year which constitutes 45% of Turkey's total red pepper production (Anonymous, 2001). Although the final quality of processed RCP is evaluated by a number of different indices, colour and pungency levels are the most widely used quality characters (Kim et al., 2002). Pepper quality is commercially evaluated on the strength of its red colour. Pepper of a deep red colour is classified as *Grade A*; pepper of a normal red colour is classified as *Grade B*; and pepper of red colour mixed with yellow and brown colours is classified as *Grade C*. The colour of red pepper is controlled by several carotenoids (capsanthin, capsorubin, and xanthophylls for the red colour, and β-carotene and zeaxanthin for the yellow-orange colour) (Ittah et al., 1993; Minguez-Mosquera and Hornero-Mendez, 1994). The degradation of carotenoids in red pepper is an auto-catalytic oxidative reaction. The rate of reaction depends on energy supply in the form of light or heat, molecular oxygen availability and the presence of antioxidants (Carnevale et al., 1980; Klieber and Bagnato, 1999). The pungency of chili pepper is directly related to

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doi:10.1016/j.jspr.2010.02.002

the pungency of the *Capsicum* fruits, which are processed into the final product. Pungent components, peculiar to the fruits of *Capsicum* plants, are the capsaicinoids. The capsaicinoids identified in *Capsicum* fruits are vanillylamides of branched fatty acids, with 9–11 carbons, of which capsaicin (vanillylamide of 8-methylnon-trans-6-enoic acid) and dihydrocapsaicin (vanillylamide of 8 methylnonanoic acid) make up more than 80%. The remaining derivatives are found in very small amounts. Many studies investigating growing conditions, physiological aspects and derived products such as paprika and oleoresins have been carried out on the capsaicinoids of *Capsicum* fruits. However, effects of post-harvest applications, such as drying, milling, heating, irradiation and storage on the capsaicinoids have rarely been considered. Post-harvest studies of capsaicinoids have been mostly concentrated on the efficiency of extraction methods (Peusch et al., 1997; Contreras-Padilla and Yahia, 1998; Zewdie and Bosland, 2000, 2001; Artık et al., 2001; Titze et al., 2002; Topuz and Ozdemir, 2004).

Several technical and economic problems have been reported for the processing and storage phases of Turkish RCP production (Isikber et al., 2007). The surveys proved the presence of xerophilic mould species, especially *Aspergillus fumigatus* Fresenius, *Aspergillus parasiticus* Speare, *Aspergillus flavus* Link ex Fries, *Aspergillus niger* van Tieghem, and *Aspergillus ochraceus* Wilhelm in most pepper samples (El-Kady et al., 1995; Adegoke et al., 1996; Freire et al., 2000; Vrabcheva, 2000). Red pepper is sensitive to the formation of aflatoxin depending on the processing conditions (Coksoyler, 1999). Fungal contamination increases the risk of aflatoxin development on the chili peppers. Both the lack of a cleaning process of freshly-harvested chili pods and the traditional solar drying method in the open, increase the risk of fungal and subsequent mycotoxin occurrence on the chili peppers. Once the chili peppers have dried to 10–12% moisture content, they are liable to reabsorb moisture by exposure to high ambient humidity during prolonged storage. The products then become vulnerable to renewed fungal attack and the possible development of mycotoxins, which introduces the risk of unacceptable toxic effects and adversely affects taste and aroma. Stored-product insects can also damage chili peppers during long-term storage, reducing their nutritive value, affecting their handling properties and contaminating the peppers with body parts and excreta, rendering them unfit for trading. Quality deterioration of chili peppers also occurs during storage due to oxidative processes that result in changes in the colour pigments (Oztekin et al., 2006). In the present study, quality indices including mould growth, aflatoxin occurrence, colour, organoleptic characters, and quality damage of red chili peppers stored under vacuum and in airtight (henceforth termed hermetic) conditions were compared with the traditional storage method.

2. Materials and methods

2.1. Experimental set-up of the vacuum–hermetic storage system

A semi-commercial scale trial was conducted in a red chili pepper processing company, Biberyum Ltd. located in Gaziantep, Turkey. Two new transportable flexible storage units of 5 m^3 capacity, the "Volcani Cube™" or "GrainPro Cocoon™" as described by Navarro (2006), were used. The system was originally designed for hermetic storage. The cubes and pump were modified for the low pressure applications.

2.1.1. Modifications of the cube

The vacuum pump was connected to the enclosure with a hard PVC 1.5″ tube located at the base of the cube. The hard tube was connected to a flexible 1.5″ tube through a one-way vacuum line valve with a quick release connection. The one-way valve was required to render the system modular, enabling the user to connect several cubes to the same vacuum pump or disconnect one of the cubes without changing the pressure in the other cubes connected. A small outlet at the top of the cube was added to obtain an accurate measurement of pressure in the cube, and a 6 mm tube was connected directly to the sensor of the vacuum pump transducer.

2.1.2. Modifications of the vacuum pump

Low pressure in the cubes was established using a rotary vane oil-lubricated vacuum pump. In order to minimize dust particle and commodity vapour damage to the pump, a dust and a carbon filter were added at the flexible 1.5″ tube connection of the pump. The predetermined pressure was monitored by a control panel to restart the pump when the pressure in the cube started to increase. The control panel was connected to a pressure transducer to provide the pressure data needed to monitor the pump. The sensor was connected to the opening located on the top of the cube via a 6 mm i.d. tube.

2.2. The semi-commercial scale trial

The trial was conducted in a barn of the RCP processing company, Biberyum Ltd. in Gaziantep, Turkey. One tonne lots of crushed and mechanically dried RCP of 10 $\pm$ 1% moisture content was stored for 6 months under a low pressure of 80–100 mm Hg, in a sealed hermetic condition, or by the traditional storage method (bags on pallets in warehouses) as a control. The selected site was a level concrete floor. The warehouse was 80 m in length by 70 m in width by 8 m height. A web of brick size holes providing ventilation for the storage warehouse was present in the walls near the roof when the doors were closed. Each hermetic and vacuum cube contained 40 jute bags, each weighing 25 kg. The cubes were loaded manually and stacked to a height of three layers. A control stack consisting of 2 pallets each of 20 jute bags was left in the warehouse unenclosed, without applying a vacuum or hermetic treatment.

Three samples of 5 kg each were collected from the hermetic, vacuum and control stacks before and after a 6-month storage period. The samples were taken from the top, the middle and the bottom layers. Each 5 kg sample consisted of RCP collected from sacks located at the 4 corners and in the centre of the sampled layer. In both vacuum and hermetic cubes, 14 sacks were sampled representing 35% of all the sacks in each cube. The same method was used to sample the control stack. Two data loggers (HOBO Pro Series) were placed at the bottom and the top of the RCP load to record the temperature and relative humidity (r.h.) in the hermetic, vacuum and control sacks. One data logger was placed outside the cubes to record the ambient conditions in the storage area. Pressure was monitored using continuous reading transducers in the vacuum treatments. Oxygen (O_2) and carbon dioxide (CO_2) levels in hermetic storage container were monitored using a hand-operated O_2/CO_2 analyzer (PBI Dansensor).

2.3. Colour measurements

Surface colour of chili pepper samples was measured before and after the 6-month storage period using a colorimeter (Minolta Co.; Model: Chroma cr-100). Colours are specified in CIELAB colour space using three coordinates: L^* (similar to Munsell value), a^* (denoting hue on the red-green axis), and b^* (which denotes hue on the yellow–blue axis). The L^* axis represents lightness ranging from no reflection for black ($L = 0$) to perfect diffuse reflection for white ($L = 100$), the a^* axis is the redness ranging from negative