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Application of Sealed Flexible Vacuum – Hermetic Storage System for Quality Preservation of Turkish Red Chili Pepper

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Abastract: In this study hermetic and vacuum storage methods were tested under small commercial scale by comparison with traditional storage methods in the warehouse, assessing the quality parameters of Turkish red chili peppers (RCP). One ton of crushed and mechanically dried RCP with maximum 10 1% of moisture content were stored for 7 months under a low pressure of 80 – 100 mm Hg, sealed hermetic conditions with traditional storage method (open piles in warehouses) used as control. Basic quality parameters related to moisture contents, color, microbial loads and aflatoxin, were determined before storage and after 7 months storage. Field scale trials indicated that the best quality red chili pepper resulted from vacuum storage with very low changes in quality parameters (pungency, colour, aflatoxin). Although hermetic storage resulted in high level losses of colour, microbial growth and aflatoxin contamination were prevented, and the pungency of red chili pepper was preserved. This study successfully demonstrated the feasibility of commercial application of hermetic and vacuum storage technology for long-term storage of red chili pepper for the first time in the world. Vacuum technology was proven to be an effective, chemical-free and economical method to disinfest commodities of insects, to inhibit the development of moulds, aflatoxin occurrence and to prevent quality damage of red chili pepper due to the oxidative and fermentative processes. In conclusion, this small scale commercial study indicates that sealed flexible vacuum-hermetic storage technology offered potentially significant advantages over traditional storage methods in ability to enhance preservation of quality parameters such as colour, pungency and control of aflatoxin of RCP for long-term storage

Key words: red chili pepper, aflatoxin, colour, *Capsaicin*, vacuum, hermetic storage

Introduction

The *Capsicum* species of red chili peppers are grown worldwide for fresh fruit and spices production. The main types of spices are powders that are derived from hot, red – coloured chili fruit or from mild, red – coloured paprika fruit. The resulting spice is referred to as chili or paprika spice. The red Chili pepper (*Capsicum annum* L.) is an extremely important crop for the Turkish food industry as well as world food sector. It is mainly produced in South and West Anatolia, and Marmara regions in Turkey. Almost all of the produced red pepper in South Anatolia region of Turkey is largely processed into spices, while the other regions produced it for fresh consumption and red pepper paste or sauce(ztekin et al. ,1999). Red chili peppers especially produced in Kahramanmaras, Gaziantep and anl urfa province of Turkey are well known for their pungent taste and flavours. Other red pepper spices produced in Kayseri, Bursa and Bilecik provinces are also famous for their sweetness. Although both the pungent and non-pungent red peppers are very important crops having high export potential for Turkey, main focus of this research is red chili pepper for spices production.

On the average, production of powdered and crushed RCP in Kahramanmara and surrounding areas is about 18 000 tones/year which constitutes 45% of Turkey's total red pepper spices production of around 40 000 tons/year (Anonymous, 2001). Although the final quality of processed RCP is assessed by a number of different parameters, colour and pungency levels are accepted as the most obvious parameters (Kim et al. ,2002). However, taste and flavour of non-pungent paprika powders are also important. In addition the spice trade may specify limits of impurity, levels of microbial counts of fungi, yeasts, *Salmonella* and coli-

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forms, particle size and moisture content. Red pepper is a very sensitive product for aflatoxin formation depending on suitable processing conditions (Coksoyler, 1999). Many survey showed the presence of xerophilic mould species, especially *Aspergillus fumigatus*, *A. flavus*, *A. niger*, *A. ochraceus*, in most pepper samples (El – Kady et al., 1995; Adego et al., 1996; Freire et al., 2000; Vrabcheva, 2000).

There are several major technical and economic problems in the processing and storage phases of Turkish red chili pepper (RCP) production. Fungal contamination greatly increases the risk of *aflatoxin* development on the chili peppers. Both the lack of a cleaning process of the freshly harvested chili pods and the traditional solar drying method in the open, increase the risk of fungal and subsequent mycotoxin development on the chili peppers. Once the chili peppers have been dried to 10% to 12% moisture content they are liable to reabsorb moisture by exposure to ambient humidity during their prolonged storage period. Then they become vulnerable to renewed fungal attacks, and possible development of mycotoxins, which is highly detrimental to their taste and aroma, and increases the risk of toxic residues. Stored product insects can also damage and contaminate the chili peppers during long-term storage by reducing their nutritive value, affecting their handling properties and contaminating them with body parts and excreta, all of which reduce their quality. Moreover, there is a serious problem of quality deterioration of chili peppers during storage due to the oxidative processes that result in changes in the color pigments (ztekin et al., 2006). These problems associated with the manufacturing and storage of chili peppers reduce the competitive power of Turkey on the international market and decrease Turkey's share of this lucrative export commodity.

Objective

The primary objective of this study is to store a high volume of red chili pepper under vacuum and hermetic conditions using sealed flexible PVC storage containers (Vacuum – Hermetic Fumigation (V – HF) technology). Storage of this commodity under vacuum and hermetic conditions was studied in comparison with their storage by traditional method (in open piles in warehouses) by evaluating some quality parameters including mould growth, aflatoxin occurrence, insect infestation and quality damage.

Materials and Methods

Experimental Set up of Vacuum – Hermetic Storage System

A small scale commercial trial was conducted in a red chili pepper processing company, BBERYUM Ltd in Gaziantep, Turkey. In this study we used two new transportable flexible storage units of 5 m^3 capacity each termed the "Volcani Cube™" or "GrainPro Cocoon" originally designed for hermetic storage. To adapt the hermetic cube system to work under low pressures, modifications were made on the cube and the pump:

a. Modifications of the cube

The connection between the vacuum cube and the pump is through a hard PVC 1.5″ tube located at the base of the cube. This hard tube is connected to flexible 1.5″ tubing through a one – way vacuum line valve by a quick release connection. The one – way valve is 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 connected cubes. To enable accurate measurements of the pressure in the cube, a small outlet at the top of the cube was added, and a 6 mm tube was connected directly to the sensor of the vacuum pump transducer;

b. The modifications on the vacuum pump

The low pressure in the cubes is established using a rotary vane oil – lubricated vacuum pump. In order to minimize damage to the pump by dust particles and commodity vapors, two filters, a dust filter and a carbon filter, were added at the flexible 1.5″tube connection to the pump. The pressure is monitored by a control panel for on and off mode of the pump at a predetermined pressure and starting it again when the pressure in the cube rises above a desired pressure. To provide the control panel with the pressure data needed to monitor the pump, the control panel is connected to a pressure transducer, the sensor of which is connected via a 6 mm i. d. tube to the opening on top of the storage cube.

Description of Small – scale Commercial Trial

The trial was conducted in a warehouse of a red chili pepper processing company, BBERYUM Ltd in Gaziantep, Turkey. One ton of crushed and mechanically dried RCP with maximum 10% ± 1% moisture content were stored for 7 months under a low pressure of 80

-100 mm Hg, sealed hermetic conditions with traditional storage method (open piles in warehouses) used as control. The selected test site was a level concrete floor in a warehouse. The warehouse was 80 m in length by 70 m width by 8 m high. On the walls near the roof there was a web of brick size holes providing ventilation of the storage warehouse when the doors were closed. Each hermetic and vacuum cube contained 40 jute bags, each weighing 25 kg (total 1 000 kg per cube). The cubes were loaded manually and stacked to a height of three layers. A control stack consisting of 2 pallets, 20 jute bags per pallet, for a total of 40 jute bags was used without applying vacuum, leaving opened in piles in warehouses.

Three samples of 5 kg were collected from each hermetic and vacuum cubes, and from the control stack before and after 7 months storage. The samples were taken from the top, the middle and the bottom layer. Each sample of 5 kg was a combined sample of red chili pepper collected from sacks located at the 4 corners and center of the sampled layer. In each of the vacuum and hermetic cube, 14 sacks were sampled representing 35% of all sacks in each cube. The same method was used to sample the control stack, 14 bags were sampled representing 35 % of all sacks.

Two data loggers (HOBO Pro Series) were inserted in the hermetic and vacuum cubes and in the control stack, one at the bottom and one at the top to record the temperatures and r. h. during the trials. One data logger was placed outside the cube for 7 months vacuum and hermetic storage 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) level in hermetic storage container were monitored by using hand - operated O_2/CO_2 analyzer (PBI Dansensor).

Quality Analysis

Basic quality parameters related to moisture contents, color, microbial loads, and aflatoxin were determined before storage and after 7 months storage.

Colour Measurement

Surface colour of chili pepper samples was measured before and after 7 months storage by using a colour meter (Minolta Co.; Model: Chroma cr - 100). The colour meter was calibrated against a standard calibration plate of a white surface and set to CIE Standard Illuminate C. The display was set to CIE $L^* a^* b^*$ colour coordinates. At least six random readings per sample were recorded and the average values of colour parameters (L^*, a^*, b^*, C^* and H) with standard deviation values and the colour difference (ΔE^*, ΔL^*, Δa^*, Δb^*, ΔC^* and ΔH^*) were reported. The colour brightness coordinate L^* measures the whiteness value of a colour and ranges from black at 0 to white at 100. The chromaticity coordination a^* and b^* have no specific numerical limits. The coordinate a^* represents red when positive and green when negative, while the coordinate b^* represents yellow when positive and blue when negative. The metric chroma C^* and metric hue angle H^* were derived from the values for CIE $L^* a^* b^*$ colour coordinates. ΔE^*, ΔL^*, Δa^*, Δb^*, ΔC^* and ΔH^* were used to describe the colour quality difference (Anonymous, 1996).

Microbiological Analysis

Representative 10 - g portions of red chili pepper from each sample were aseptically weighed and homogenized with 90 mL sterile peptone - physiological saline (0.1 % w/v neutral peptone, 0.85 % w/v sodium chloride, pH 7.2). Serial decimal dilutions were prepared with the same diluents, duplicate counting plates were prepared using appropriate dilutions. After incubation at appropriate temperatures, the colonies that appeared on the selected plates were counted as colony forming units (cfu) per gram weight sample. The surface spread method was used for total aerobic mesophylic bacteria (Nutrient Agar (NA) - Merck) and yeast/moulds (Potato Dextrose Agar (PDA) - Merck) at 30 ℃ for 48 - 72 h, 25 ℃ for 3 - 5 days, respectively (Borcakli et al., 1994; Temiz, 1996). *E. coli* and coliform were determined by the MPN method (3 tubes) on Florocoult Laurly Sulfate Broth (Merck) at 37 ℃ for 24 hours (Williams and Busta, 2000; Borcakli et al., 1994)

Aflatoxin Analysis

Samples were analyzed using the validated method of Association of Official Analytical Chemists International (AOAC, 2000). All samples were finely ground, thoroughly mixed, extracted and filtered. The immunoaffinity column was diluted with 60 mL PBS and applied to the conditioned column (2 - 3 mL/min). After that, the column was washed with 15 mL water (5mL/min) and dried by passing air through it. Finally, bound aflatoxins were eluted slowly with 2 mL methanol. All reagents were of recog-

nized analytical grade. The presence of aflatoxins was detected by high performance liquid chromatography (HPLC) using a post – column derivitisation electrochemically generated bromine (cobra cell) and a fluorescence detector.

Capsaicin Analysis

Capsaicin is quatitated using the isocratic HPLC method of Woodbury. (1980). Sample extracts was obtained by soxhleting 10g of ground peppers with 250 mL of HPLC grade acetone (Merck) for 5 hours. The extract was vacuum evaporated to 5 mL at room temperature. Bisphenol A (Aldrich), a common antioxidant was used as an internal standard. 1 g of oleoresin and 30 mg Bisphenol A were dissolved in 5 mL acetonitrile (Merck). A 2 mL aliquot was filtered through a Sep – pak C – 18 cartridge (Alltech). Ten microliters of this sample were injected directly to the HPLC system (Waters Associates Model ALC/GPC equipped with aM. 6000A pump, a U6Kinjection). The column was – Bondapak C – 18 column (300 × 4 mm, 5 m). Separation was accomplished via a variable wavelength UV detector (Water Associates) set at 280 nm. The isocratic mobile phase was methanol: water (60:40) with a

Data Analysis

Statistical analysis was performed by analysis variance (ANOVA) and Duncan's multiple range test to establish the actually differing applications. All these statistical studies were conducted using the SPSS software (SPSS Inc., version 11.0).

Results and Discussion

Daily temperature (C) and relative humidity changes (%) during (a) vacuum, (b) hermetic and (c) traditional storage of red chili pepper for a period of 7 months are given in Figure 1. Hermetic and vacuum storage effectively prevented moisture exchange between the surrounding air and the red chili pepper. There was only a slight increase in relative humidity of 2% and 5.2% in the hermetic and vacuum storage respectively. In contrast, relative humidity of control treatment (traditional storage) showed great fluctuations during the storage period, ranging from 32.5% to 82.1%. This result indicates that the moisture content of red chili pepper in open storage can be increased, mainly through moisture content exchange with the surrounding ambient air. It appears that there was not much difference in temperature changes in hermetic, vacuum and traditional storage. Similar results for other commodities such as barley, paddy rice and corn etc. have been reported by Varnava et al. (1995), Navarro et al. (1998) and Donahaye et al. (1999).

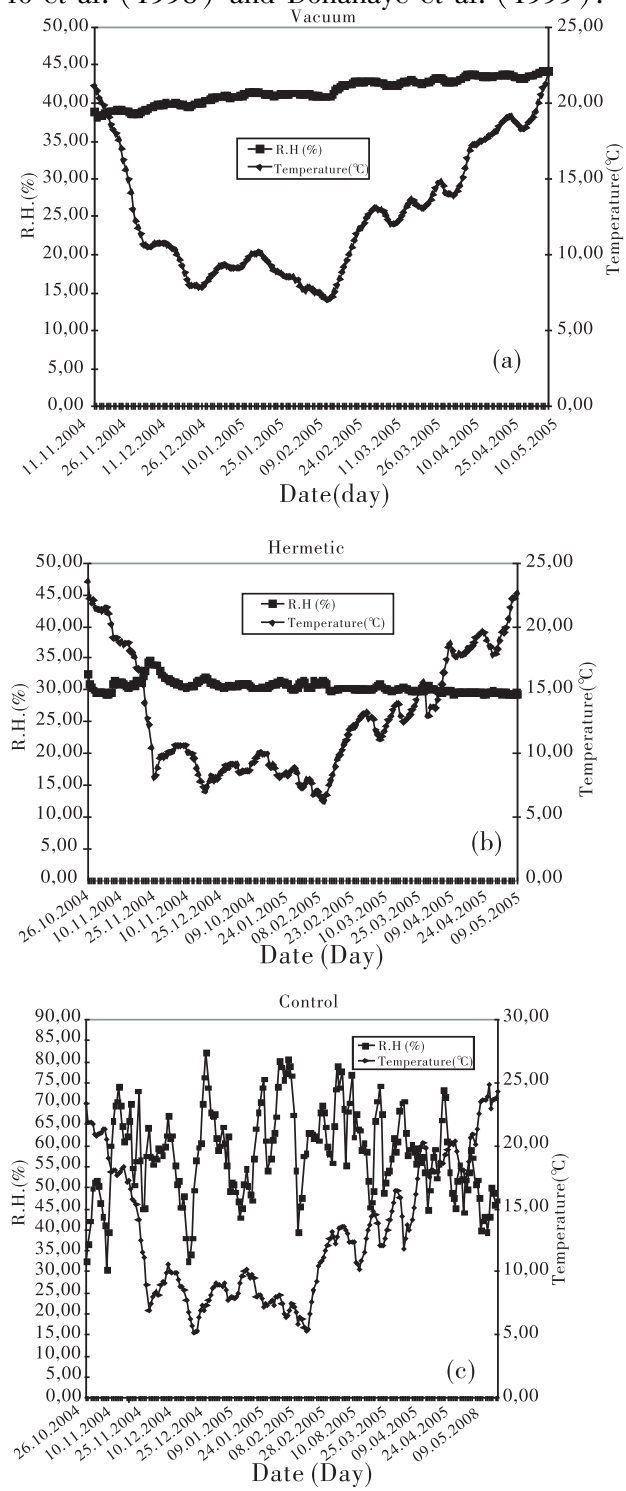

Fig. 1 Daily temperature (℃) and relative humidity changes (%) during (a) vacuum, (b) hermetic and (c) traditional storage of red chili pepper for a period of 7 months.

Colour stability of red chili pepper stored under different storage methods for a period of 7 months is given Table 1. Storage methods had a

significant influence on colour parameters of L^* (colour brightness), a^* (redness) and b^* (yellowness). After 7 months storage of RCP by traditional storage method, a considerable decrease in L^*, a^* and b^* values of RCP samples was found as compared to their initial average colour parameters. However, the L^* and a^* values after 7 months storage under hermetic condition indicated a considerable increasing tendency, while no significant difference in a^* values of RCP samples were found as compared to their initial average redness values. Contrary to these two storage methods, no significant change in all three colour parameters of RCP samples stored under vacuum for 7 months was found as compared to their initial average colour parameters. It appears that vacuum storage method gave the best results having retained initial reddish orange colour of RCP samples during 7 months storage. Similarly, Klieber (2000) reported that the most effective treatment was storing red chili pepper powder under nitrogen or vacuum; this reduced the weekly rate of colour loss to 3% – 5%. It was effective as oxygen that is needed for colour pigment autoxidation was excluded.

Table 1. Colour stability of red chili pepper stored under different storage methods for a period of 7 months

Storage method	Colour difference models				
	ΔL^*	Δa^*	Δb^*	ΔC^*	ΔH^*
Control	−4.128	−3.217	−7.500	−8.027	1.471
Hermetic	6.428	−0.333	7.539	6.324	4.117
Vacuum	−1.002	−2.761	−2.408	−3.534	0.966

Changes of microbiological parameters during vacuum, hermetic and traditional storage of red chili pepper for a period of 7 months are given in Table 2. Mould-yeast count in RCP samples stored by traditional storage method was increased significantly compared to their initial counts, whereas no significant change in mould-yeast count was found by vacuum and hermetic storage methods. As a result of this, there was an increase in Aflatoxin B1 and of total aflatoxin (B1 + B2 + G1 + G2) (g/kg) on RCP samples stored by traditional storage method for long-term storage, while no increase in Aflatoxin B1 and of total aflatoxin on RCP samples was found by vacuum and hermetic storage. Whereas there was a decrease in TAMM (total aerobic mesophyllic microorganism) count by vacuum and hermetic storage, significant increase in TAMM count was found by traditional storage methods compared with its initial count. The counts of coliform group bacteria and *E. coli* were found no significant change by all storage methods compared to their initial methods.

Table 2. Changes of microbiological parameters during vacuum, hermetic and traditional storage of red chili pepper for a period of 7 months

Parameters	Before storage	Control	Hermetic	Vacuum
Aflatoxin B1 (μg/kg)	<0.2	1.56	<0.2	<0.2
Total Aflatoxin (μg/kg)	<0.5	1.79	<0.5	<0.5
TAMB (cuf*/g)	2.1×10^5	5.2×10^6	3.9×10^3	1.1×10^4
Yeast – Mould (cuf/g)	3.3×10^4	3.6×10^5	3×10^4	2.7×10^3
Coliform (cuf/g)	<7	<7	<7	<7
E. coli (cuf/g)	<3	<3	<3	<3

* cuf: colony unit forming

Changes of capsaicin level and moisture content during vacuum, hermetic and traditional storage of red chili pepper for a period of 7 months are given Table 3. There was a significant reduction in capsaicin level of RCP samples stored by hermetic and traditional storage methods, compared to the initial levels before the storage. The highest reduction in capsaicin level of RCP samples stored by traditional methods was found and followed by hermetic storage method. Having no significant difference in capsaicin level of RCP samples stored by vacuum method compared to their initial levels, vacuum storage also indicated the best option of preserving the pungency levels of RCP during its prolonged storage period. Laboratory trials indicated that red chili pepper needed to be stored under vacuum, hermetic and high – CO_2 conditions to slow the loss of pungency during long-term storage (Isikber et al., 2006). Our result was in line with the results reported by Isikber et al. (2006). There was a significant increase in moisture content of RCP samples stored by traditional storage method for a period of 7 months, whereas no significant increase in their moisture contents was found by vacuum and hermetic storage. It indicates that RCP stored by traditional method are liable to reabsorb moisture by exposure to ambient humidity

during their prolonged storage period.

Table 3. Changes of capsaicin level and moisture content during vacuum, hermetic and traditional storage of red chili pepper for a period of 7 months

Parameters	Before storage	Control	Hermetic	Vacuum
Capsaicin level (mg/kg)	89.79 ± 0.38 A	83.01 ± 0.25 C	86.10 ± 0.31 B	88.35 ± 0.22 AB
Moisture content (%)	10.03 ± 0.25 A	12.38 ± 0.19 B	10.47 ± 0.28 A	9.68 ± 0.31 A

Different upper case letters indicate significant differences among means within a row for a particular activity (ANOVA followed by LSD, $\alpha = 0.01$).

Small scale commercial trials indicated that the best quality red chili pepper resulted from vacuum storage with very low changes in quality parameters (pungency, colour, aflatoxin). On the other hand, hermetic storage resulted in high level losses of colour, while microbial growth and aflatoxin contamination were prevented, and the pungency of red chili pepper was preserved. In conclusion, this small scale commercial study indicates that sealed flexible vacuum-hermetic storage technology offered potentially significant advantages over traditional storage methods in ability to enhance preservation of quality parameters such as colour, pungency and aflatoxin of RCP for long – term storage.

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