Sen F, Meyvaci KB, Turanli F, Aksoy U (2012) Influence of controlled atmosphere treatment on storage pests and quality of sun-dried fig fruits. In: Navarro S, Banks HJ, Jayas DS, Bell CH, Noyes RT, Ferizli AG, Emekci M, Isikber AA, Alagusundaram K, [Eds.] Proc 9th. Int. Conf. on Controlled Atmosphere and Fumigation in Stored Products, Antalya, Turkey. 15 – 19 October 2012, ARBER Professional Congress Services, Turkey pp: 517-522

INFLUENCE OF CONTROLLED ATMOSPHERE TREATMENT ON STORAGE PESTS AND QUALITY OF SUN-DRIED FIG FRUITS

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ABSTRACT

Sun-drying of fruit is a local practice especially under mild climatic conditions. In western Turkey, fig drying destined for the world market is a commercial practice. Prevention of storage pests attacking figs at the orchard while drying and later during storage is of major concern for the dried fig industry. Before the phase-out of methyl bromide (MB) was the most widely used fumigant to control storage pests due to its efficacy and low cost. After the ban, various alternatives are tested. A trial is designed to test controlled atmosphere in a pilot chamber developed by EcO2 (EcO2 B.V., AG Numansdorp, The Netherlands). Short term controlled atmosphere (CA) (%12±0.5 CO_2, %1±0.5 O_2, balance N_2 fumigation at elevated temperature (41±1°C) is tested on dried figs to control major storage pests, fig moth (*Ephestia cautella*), Indian meal moth (*Plodia interpunctella*), and dried fruit beetle (*Carpophilus* spp.), Dried fruit treated with MB (60 g/m^3 for 24 h) as control were compared with fruit fumigated with CA after the treatments and during 6 months storage under ambient conditions to assess quality changes. The tested CA treatment is recommended as a post-harvest MB alternative for dried figs since it provided 100% control of the pest species tested and required circa 26 h for the completion of the whole process which is comparatively shorter than most MB alternatives. CA application had no negative impact on dried fig quality, on the contrary had a positive effect by slowing down sugar formation on the outer skin at storage.

Key words: *Ficus carica* L., fig moth, Indian meal moth, dried fruit beetle, heat treatment, dried fruit quality

INTRODUCTION

Dried fig production and commercial sun-drying based on a single cultivar, (*Ficus carica* Sarilop (= Calimyrna)) is an important activity in the western part of Turkey. Dried fig trade may continue all year long if fruit quality is kept well and storage pest infestation is prevented. Storage pests especially the fig moth (*Ephestia cautella*; Pyralidae: Lepidoptera) and *Carpophilus hemipterus* play important role in the quality and consequent trade volume of dried fig (Turanlı, 2003). Large populations can develop before being discovered and considerable damage may occur.

Due to ban on MB, alternatives are developed but all having some limitations that prevent it from being a real substitute (Bell, 2000; Damarli et al., 1998; Johnson et al., 2000; Fields and White, 2002; Schneider et al., 2003; Aksoy et al., 2004). Controlled atmospheres

(CA) can be an alternative to MB under certain conditions. Adults of dried fruit beetle, *Carpophilus hemipterus* (L.) is relatively tolerant to heat and exposure of 20-60 min is required to achieve complete mortality at 50°C (Al-Azawi et al., 1984). *Ephestia cautella*, *Ephestia kuehniella and Plodia interpunctella* are accepted as the most tolerant species (Fields and White, 2002). Navarro et al. (2004) recommended heat treatment at 50-55°C as a MB alternative for disinfestations of dates. Higher temperatures increase efficacy of insecticide applications that target the respiratory system and for short exposure periods, low-oxygen application at higher temperatures can be considered (Donahaye et al., 1996).

The objective of this study was to investigate the potential use of controlled atmosphere (CA) with reduced oxygen level at elevated, but safe for product quality, temperature for the control of *E. cautella, P. interpunctella* and *Carpophilus spp.*

MATERIAL AND METHOD

The research was carried out on extra quality sun-dried fig (*Ficus carica* L. cv. Sarılop) fruits in a pilot fumigation chamber designed by EcO2 (EcO2 B.V., AG Numansdorp, the Netherlands). Controlled fumigation conditions were tested with lots each containing 1 ton (40 boxes) of dried fig fruit. The initial stage of the treatment comprised of increasing fig fruit temperature to 41°C and lowering O_2 concentration to 1±0.5 % followed by an increase of CO_2 to 12±1%. The safe maximum temperature level (<45°C) is decided based upon the results obtained in a series of tests undertaken to assess fruit quality changes at various temperatures (data not shown). Dried fig fruit were kept for further 16 hours at tested conditions for further penetration into the fruit tissue. The whole system was monitored and modified when necessary by a computer. The temperatures were recorded in the chamber atmosphere, inside boxes and inside the fig fruit. Fruit fumigated under controlled atmosphere conditions were stored at ambient storage conditions for six months, and quality changes were compared with methyl bromide treated control (60 g/m^3 for 24 h) fruit.

Existing natural infestation levels were recorded as the number of larvae of mixed population of *Ephestia cautella* and *Plodia interpunctella*. The dried fruit beetles, *Carpophilus* spp. was evaluated as the number of infested fruits. During the experiments, culture jars containing fruits infested by different stages of storage pests larvae of lepidopteran pests and *Carpophilus* spp. were placed inside the chamber. The tests were carried out as 5 replicates, each replicate containing 7 fig fruit infested with each pest group. Culture jars were examined 6, 12, 24 hours and 14 days after the treatment in the laboratory to evaluate the effects of applications on mortality of storage pests.

Dried fig fruit quality was evaluated after the treatments and at 2 months intervals during 6 months storage under cold storage conditions. Samples were dried in a vacuum oven to a constant weight (AOAC, 1990), and fruit moisture content was calculated based on the percentage of weight loss. Water activity was measured at 25ºC by a water activity meter (TH 500, Novasina, Pfaeffikon, Switzerland). The surface color of dried figs was measured on opposite sides of 25 fruits randomly taken by a colorimeter (CR-300, Minolta Co., Osaka, Japan), and average scores were recorded in terms of CIE-L* a* b* values.

A Nippon FHR-1 penetrometer possessing a conical tip (base diameter 12 mm and length 10 mm) was used to measure firmness, and the results were expressed as Newton (N). Total soluble solids content (TSS) was determined with a refractometer (ATC-1, Atago, Japan) and expressed as g/100 g.

Sugaring on the outer surface was evaluated visually on a 1–5 scale, each class describing the surface area covered by white sugar crystals (1; no sugaring to 5; complete cover with sugar). The sugaring index of the sample was calculated using the following formula: (sugaring class value (scale) x number of fruits within each class)/total number of fruits (Aksoy et al., 2004).

Fluoresence on dried fig fruit were evaluated visually under long wave (360 nm) UV light. 8 plates, each containing 10 fruits showing BGYF were prepared to assess if the tested treatments have any effect on BGYF since BGYF fruit are removed during processing to decrease aflatoxin contamination. The BGYF area was marked on each fruit with a board marker and the intensity of BGYF was evaluated as very soft: 1, soft: 2, medium: 3, strong: 4, very strong: 5. Half of the plates underwent the aforementioned treatments together with the other fruits in the experiments. The individual treated and non-treated fruits were examined by two panelists already trained on BGYF. Additionally, 8 panelists were asked to compare treated and non-treated samples in respect to BGYF intensity.

The experiments were conducted as completely randomized design with five replicates (except BGYF test). All computation and statistical analyses were done using SPSS (SPSS, Inc., Chicago, IL, USA) package version 19.0. Significant differences between the means for each storage period were determined by Duncan's multiple range tests at $P \leq 0.05$. Standard deviation of the mean (*SD*) was also calculated from the replicates.

RESULTS AND DISCUSSION

Mortality of test insects

The natural infestation level of fruit samples was 10.0 % before the treatments. The *Carpophilus* spp. infested fruit rate was 7.4%. 100 % mortality was obtained in tested stages of the targeted stored pests 6 hours after the CA treatment. The total fumigation process including heating, CA exposure and aeration lasted for 26 hours.

Fruit quality

Dried fig fruit colour L* (lightness) value was lower ($P \leq 0.05$) and b* (yellowness) value higher ($P \leq 0.01$) in Controlled Atmosphere (CA) treated fruit compared to MB treated. This difference in colour (b*) continued till the second month however equalized later towards the end of the storage (Table 1). This difference could also be due to the sampling as variations are seen in 0-2-4 month results of MB treated fruit. Colour a* value of CA treated fruit were similar to MB treatments throughout the storage. Fruit colour may change during drying and storage due to a number of chemical and biochemical reactions. In most cases, Maillard reaction, a non-enzymic browning, occurs in dried fruit (Roos and Himberg, 1994; Perera and Baldwin, 2001). The darkening continue in storage however the rate depends both on the substrate and on that is related to the substrate and the storage conditions (Perera, 2005). Turkish dried figs are known for their light colour therefore colour is accepted as a major quality attribute.

CA treatment had marked effect on water activity ($P \leq 0.05$) and moisture contents ($P \leq 0.01$) of treated fig samples (Fig 1A and Table 2) possibly as a result of enhanced moisture loss at elevated temperatures. The moisture destined to the chamber atmosphere is further channeled out prior to inlet of nitrogen gas letting lower moisture content in the chamber. However, this difference was lost after two months of storage since moisture transfer continues until fruit moisture reaches to equilibrium with the exposed atmosphere. Loss of moisture from dried fig fruit may harden the texture and thus reduce palatability if at severe rates (Sen et al., 2008; Sen et al, 2010) however the reduction rate was not at levels that could have considerable effect on firmness (Table 2). Similarly, the effect on TSS was also negligible. Lower water activity levels obtained in CA treatment allowed dried fruit to be at safer levels in respect to microbial growth even at the initial stage of processing (Fontana, 1987).

Table 1. Effect of MB (60 g/m3 for 24 h) and CA (1% O_2, 12% CO_2, balance N_2 at 41^{o}C for 16 h) treatments on surface color (CIE L*, a*, b* values) of dried fig fruit measured after treatment and during storage.[z]

Storage period	L* value		a* value		b* value	
	MB	CA	MB	CA	MB	CA
0. Month	58.43±1.16 a[x]*	56.68±2.56 b	4.68±0.21^{NS}	5.36±0.19	24.25±0.83 b**	28.29±1.07 a
2. Month	59.43±1.36^{NS}	58.29±2.39	4.41±0.16^{NS}	4.86±0.18	22.82±0.78 b*	25.02±0.99 a
4. Month	58.20±1.98^{NS}	56.95±2.24	4.66±0.24^{NS}	5.21±0.33	21.65±0.83^{NS}	22.74±0.87
6. Month	55.05±1.21^{NS}	56.08±2.45	5.15±0.16^{NS}	4.39±0.22	16.28±0.55^{NS}	18.25±0.61

^{NS}, *, **, Nonsignificant or significant at *P*≤ 0.05, or 0.01, respectively.
[z] Results are the means of five replicate samples ±SD.
[x] Means for each experiment were separated within columns by Duncan's multiple range test, P <0.05.

Table 2. Effect of MB (60 g/m3 for 24 h) and CA (1% O_2, 12% CO_2, balance N_2 at 41^{o}C for 16 h) treatments on surface water activity, TSS and firmness of dried fig fruit measured during the storage period.[z]

Storage period	Water activity		TSS (%)		Firmness (N)	
	MB	CA	MB	CA	MB	CA
0. Month	0,659±0,009a[x]*	0,633±0,007 b	60.0±0.3^{NS}	61.2±0.3	7.69±0.13^{NS}	7.51±0.24
2. Month	0,634±0,004^{NS}	0,620±0,003	62.0±0.8^{NS}	62.0±0.8	6.90±0.22^{NS}	7.07±0.28
4. Month	0,598±0,012^{NS}	0,607±0,008	62.3±1.3^{NS}	63.3±0.8	7.23±0.11^{NS}	7.29±0.21
6. Month	0,589±0,004^{NS}	0,582±0,005	60.9±0.8^{NS}	62.7±1.3	7.66±0.13^{NS}	7.55±0.14

^{NS}, *, Nonsignificant or significant at *P*≤ 0.05.
[z] Results are the means of five replicate samples ±SD.
[x] Means for each experiment were separated within columns by Duncan's multiple range test, P <0.05.

If dried figs are stored under unfavourable conditions that trigger moisture loss at storage, dissolved substances are transported parallel with the outer flow of water and sugar crystals form on the skin (Meyvaci et al., 2003). CA and MB treated dried figs displayed similar sugaring tendencies during storage. Incidence and severity of sugaring increase with storage temperature and time (Mitcham et al., 2012). However CA treated fruit had less sugaring compared to MB (Fig. 1B). The crystallization rate of sugars was slowed down possibly due to initial heating of the fruit.

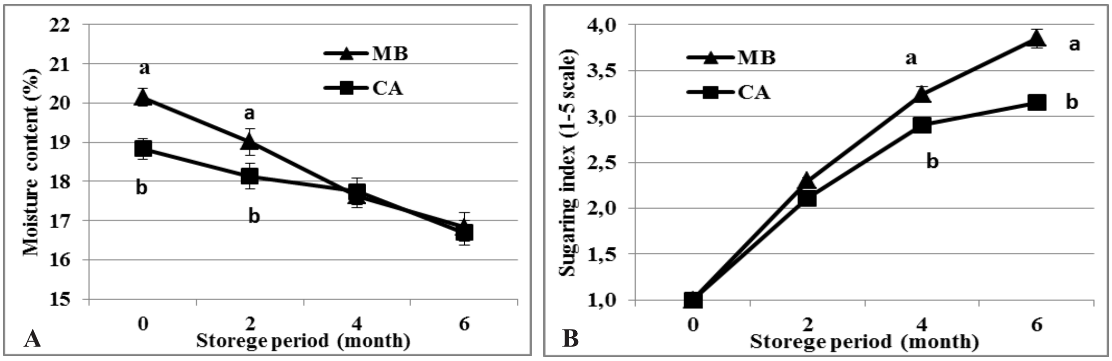

Fig. 1- Effect of MB (60 g/m3 for 24 h) and CA (1% O_2, 12% CO_2, balance N_2 at 41^{o}C for 16 h) treatments on surface moisture content (A) and sugaring index (B) of dried fig fruit measured after treatment and during storage.[z]

Bright greenish yellow fluorescence

BGYF fruit irrespective of the intensity or size of the fluorescence are known to be highly correlated with aflatoxin contamination (Steiner et al., 1985. Thus BGYF fruit are removed during processing to reduce aflatoxin levels. CA or MB treatments had no reducing or modifying effect on intensity or area of bright greenish yellow fluorescence on the fruit surface. This result shows that CA treatment prior to BGYF removal does not create any bottlenecks in dried fig processing.

CONCLUSION

The tested CA+heat treatment was effective in providing complete mortality of major dried fig storage pests, fig moth (*Ephestia cautella*), Indian meal moth (*Plodia interpunctella*), and dried fruit beetle (*Carpophilus* spp.) and had no negative impact on fruit quality of fruit stored for four months under ambient conditions. Therefore, CA treatment can be recommended to the sector as a MB alternative since it requires comparatively short duration and can be easily adapted to mobile systems. During operations, energy and gas costs need to be considered.

ACKNOWLEDGMENTS

The research is a part of the project supported by Ege University Department of Horticulture, Aegean Exporter's Associations, TARIS Fig Agricultural Sales Cooperative (Turkey) and EcO2 B.V., AG Numansdorp (The Netherlands).

REFERENCES

Al-Azawi AF, El-Haidari HS, Aziz FM, Murad AK, Al-Saud HM (1984) The effect of high temperatures on the dried fruit beetle *Carpophilus hemipterus* (L.) a pest of stored dates in Iraq. Date Palm Journal 3: 327-336.

Aksoy U, Meyvaci KB, Sen F, Altindisli A (2004) Impact of fumigants applied to control storage pests on fruit quality of dried figs. IOBC WPRS Bulletin 27: 203-209.

AOAC (1990) Official Method of Analysis, 15th ed., Association of Official Analytical Chemists, Arlington, VA.

Bell CH (2000) Fumigation in the 21st century. Crop Protection 19: 563-569.

Damarli E, Gun H, Ozay G, Bulbul S, Oechesle P (1998) An alternative method instead of methyl bromide for insect disinfestations of dried figs: controlled atmosphere. Acta Horticulturae 480: 209-214.

Donahaye E, Navarro S, Rindner M, Azrieli A (1996) The combined influence of temperature and modified atmospheres on *Tribolium castaneum* (Herbst) (Coleoptera: Tenebrionidae). Journal of Stored Products Research 32: 225-232.

Fields PG, White NDG (2002) Alternatives to methyl bromide treatments for stored-product and quarantine insects. Ann Rev Entomol 47: 331-359.

Fontana AJ (1987) Water activity: why it is important for food safety. In: Rockland LB, Beuchat LR (Eds) Water Activity**:** Theory and Applications to Food**.** Marcel Dekker, Inc., New York, pp. 287-294.

Johnson JA, Valero KA, Hannel MM, Gill RF (2000) Seasonal occurrence of postharvest dried fruit insects and their parasitoids in a culled fig warehouse. Journal of Economic Entomology 93: 1380-1390.

Meyvaci KB, Sen F, Aksoy U, Altindisli A, Emekci M, Ferizli AG (2003) Project to phase-out methyl bromide in the dried fig sector in Turkey. Acta Hort 628: 73-81.

Mitcham EJ, Crisosto CH, Kader AA (2012) Dried fruits and nuts: Recommendations for maintaining postharvest quality. http://postharvest.ucdavis.edu/PFfruits/DriedFruitsNuts/. Accessed 14 June 2012

Navarro S, Finkelman S, Rindner M, Dias R (2004) Emigration and control of nitidulid beetles from dates using heat. IOBC WPRS Bulletin 27: 219-225.

Perera CO (2005) Selected quality attributes of dried foods. Dry Technol 23: 717-730.

Perera CO, Baldwin EA (2001) Biochemistry of fruits and its implications on processing. In: Arthey D, Ashusrt PR (Eds) Fruit Processing; Nutrition, Products and Quality Management, Aspen Publishers, Gaithersburg, MD, pp.19-36.

Roos YH, Himberg MJ (1994) Nonenzymatic browning behavior, as related to glass transition, of a food model at chilling temperatures. J Agr Food Chem 42: 893-898.

Schneider SM, Rosskopf EN, Leesch JG, Chellemi DO, Bull CT, Mazzola M (2003) Research on alternatives to methyl bromide: pre-plant and post-harvest. Pest Management Science 59: 814-826.

Sen F, Meyvaci KB, Aksoy U, Cakir M (2008) Studies to optimize pre-treatments for high moisture dried figs. Acta Horticulturae 798: 293-297.

Sen F, Meyvaci KB, Turanli F, Aksoy U (2010) Effects of short-term controlled atmosphere treatment at elevated temperature on dried fig fruit. Journal of Stored Research 46: 28-33.

Steiner, W.E, Rieker R.H, Battaglia R. (1985). Aflatoxin contamination in dried figs: distribution and association with fluorescence. Journal of Agricultural and Food Chemistry 36: 88-91

Turanli F (2003) Studies on infestation levels of pests on dried fig in Aydın and Izmir provinces. Turkish J Entomol 27: 171-180.