J. of Plant Protection and Pathology, Mansoura Univ., Vol. 14 (5):139 - 145, 2023

Journal of Plant Protection and Pathology

Journal homepage & Available online at: www.jppp.journals.ekb.eg

Influence of Modified Atmospheres on Infestation of Stored Date Fruits by *Ephestia cautella* (Walker) and *Stegobium paniceum* (L)

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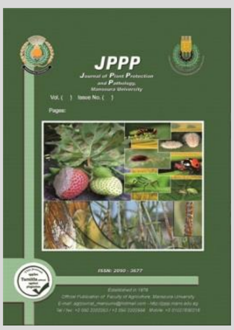

ABSTRACT

Treatment of nitrogen can be used as alternative method to chemical control against stored-product-insects. The aim of this study was to determine the effectiveness of modified atmospheres (MAs) based on high nitrogen (N_2) contents on infestation by immature stages of *Ephestia cautella* and *Stegobium paniceum*, major pests of date fruits, and their effect on the quality of date fruits. The tested MAs were 98% nitrogen gas (Oxygen 2%), in diverse exposure-times. The study found, the egg, larval, and pupal stages of *E. cautella* and *S. paniceum* responded significantly to MAs enriched by "N2" as exposure-time increased. Two days (48h) exposures of date fruits to nitrogen gas were adequate enough to complete suppression in adult emergence of *E. cautella*. While, 24 h exposure to N_2 gas was enough to suppress *S. paniceum*. Time and pest level were an influential factor that have a massive effect on the immature mortality percent and adult emergence of *E. cautella* and *S. paniceum* after exposure to N_2 gas. Furthermore, nitrogen gas did not effect on the quality of the date fruits.

Keywords: Nitrogen, *Ephestia cautella*, *Stegobium paniceum*, date fruits.

INTRODUCTION

The almond moth *Ephestia cautella* (Walker), (Lepidoptera: Pyralidae) causes severe infestations for date fruits which led to impacting their quality and quantity. This insect is known to attack various agricultural-commodities in storage include wheat, cereals, legumes and date-fruits. Under unchecked conditions, the it can completely destroy the infested item (Aldawood *et al*,. 2013; Mureed *et al*., 2017; Jian, 2019). The drugstore beetle, *Stegobium paniceum* (L), (Coleoptera: Anobiidae) is a cosmopolitan insect that has a wide range of food sources; include dried plant materials and even biological specimens in museum-collections. Further, it is a worldwide pest of stored dates and other stored products (Li *et al*., 2009; Hironaka *et al*., 2017). The adults of *S. paniceum* usually cause direct damage by gnawing their way to food storage containers, then laying their eggs in stored products.The hatched-larvae then infest these stored-materials with dead beetles and other waste products left behind which can cause additional spoilage and economic loss (Li *et al*., 2009; Benellin *et al*,. 2013). The modified atmospheres "MAs" is a prevalent in storage grains, fruits, and vegetables; and others agricultural-products. Research has shown that storing grains in "N2-MA" can significantly led to delay and deteriorations of grain quality (Wang *et al*., 2018). Additionally, previous studies have indicated "N_2-MA" storage can preserve vitamin E and polyphenols present in grains (Moncini, *et al.* 2020). Vunduk, *et al.* (2021), showed that the stored agricultural products via MA could successfully suppress α-glucosidase activity, slow down of ascorbic acid oxidations, enhance preservation of citric acid, total-phenolics and total antioxidant capacity. The application of MA technology to chickpea storage by Perez-Perez *et al*., (2021) revealed that the stability of antioxidant capacity and phenolic compounds in chickpeas was higher under N_2-MA storage condition than??????. This was attributed to oxidative-degradation prevent. Lang *et al.* (2019) provided evidence that the use of nitrogen-MA can be minimized phenolic-compounds degradation in the black rice throughout the period of storage . According to Riudavets *et al.* (2014) and Coresta (2019), MA-technology is eco-friendly alternative for pest control, safe in storage because it is not leave residues or negative impact on quality of treated products, and it poses a low risk of creating resistance in insects without any harm to human health. According to research by Athanassiou *et al.* (2017), the life-stages of the confused flour beetle *Tribolium confusum* (Jacquelin du Val. (Coleoptera: Tenebrionidae), the egg and larval stages of cacao moth, *Ephestia elutella* (Hubner) (Lepidoptera: Pyralidae), and the sawtoothed grain beetle adult of *Oryzaephilus surinamensis* (L.) (Coleoptera: Silvanidae) were killed when nitrogen was used to reduce the oxygen level to 1%.

This study therefore is conducted to evaluate influence of nitrogen gas in suppressing the *E. cautella* and *S. paniceum* populations in stored date fruits under laboratory-controlled conditions at different durations of time.

MATERIALS AND METHODS

Experiments conducted in Stored Product Pest Department, Plant Protection Research Institute, Agricultural Research Center, as well as in Laboratory of Stored Product Pests Control, Plant Protection Department, Faculty of Agriculture Benha University.

Insect cultures:

Naturally infested dried dates were used as the for *E. cautella* and *S. paniceum*. The adults obtained from established cultures were putted in glass-jars "1L-capacity" containing crushed Sewa-dates. These jars were kept in an

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DOI: 10.21608/jppp.2023.206419.1143

incubator adjusted to 28±2°C, 65±5RH%, and 16:8 Light:Dark photoperiod. To obtain eggs, newly emerged adults were daily collected and introduced in glass cages with screen bottoms after completing their life cycle. The colony was kept in the same physical conditions for six generations before experiment.

Bioassay test:

Jute bags (4×8cm) contained 20 grams of crushed Sewa date were artificially infested with 30 fourth instar larvae and 30 pupae (2-4 days old) of *E. cautella* and *S. paniceum.* Further, 100 eggs of *E. cautella* and 100 eggs of *S. paniceum* that collected from 15 pairs during 24 h. Each stage was exposed separately to nitrogen gas (98%) inside the gastight Dreshel flask of 0.55 L volume at different exposure periods (0, 3, 6, 12, 18, 24 and 48 h.). Untreated bags were kept as a control for each stage.

At the end of each exposure period, the number of living and dead was counted after 24 hours from the opening time of the Dreshel flask. The alive individuals from the different immature stages were transferred into glass jars and covered with a muslin cloth and fixed with a rubber band then incubated at temperature 28±2°C, 65%±5 R.H% and a photoperiod of 16:8 Light:Dark until adult emergence. Jars were daily examined to record emergence of adults. All treatments were replicated four times.

Chemical analysis of date-fruits:

To determine effect of "N_2" on date fruits quality, 1-Kg of fruits were exposed-to "N_2" treatments for 3-days. Chemical composition analysis of date fruits (carbohydrate, iron, calcium, and potassium) were estimated "before" and "after" treatment. 3-samples (5-fruits/sample) were analyzed. Total-carbohydrates were determined by method described by Singh and Sinha (1977). Potassium and iron levels were determined using the flame photometric according to the methods of Toth and Prince (1949). Calcium was determined using a PerkinElmer Atomic Absorption Spectrophotometer 2380 (PerkinElmer, Inc., Waltham, MA, USA).

Statistical analysis:

Data were analyzed using Proc. "ANOVA" by SAS program (Anonymous 2003) and means compared using "LSD" P = 0.05. For elucidating the differences between tested pests, stages and inspection-times, the factorial-analysis using Proc. ANOVA in SAS program was applied.

RESULTS AND DISCUSSION

Results

The egg, larva, and pupa of moth *E. cautella*, responding-to modified-atmospheres with nitrogen-gas riches 98% (Oxygen 2%) were shown in Table (1). Naturally, exposure periods influenced the mortality of artificially introduced insects. Mortalities of immature stages of *E. cautella* responding to modified atmospheres with nitrogen increased significantly (P < 0.01) with nitrogen exposure length as compared to the parallel control sample. Nitrogen gas significantly influenced the egg, larva, and pupa mortality F=105, P= 0.001, F= 78.9, p=0.0001 and F= 72.2, P= 0.0001, respectively, as compared to the parallel control sample. After a 48h exposure period, the highest mortality was 94.44, 78.33 and 85% for egg, larvae, and pupae, respectively post exposure to 48 h nitrogen gas. Likewise, the percent of adult emergence significantly decreased gradually with the increase of exposure period F=82.2, P= 0.001, F= 130.9, p=0.0001and F= 40.9, P= 0.0001, for eggs, larvae, and pupae respectively, as compared to the parallel control sample. Two days (48h) were adequate to complete suppression in adult emergence after exposure of date fruits infested with eggs and larvae of *E. cautella* to nitrogen gas.

Table 1. Effect of nitrogen gas on mortality % and adult emergence % of immature stages of *E. cautella* post exposure to nitrogen gas (98%) at different time of exposure.

Stage	Eggs		Larvae		Pupae	
Time (h)	Mortality %	Adults Emergence %	Mortality %	Adults Emergence %	Mortality %	Adults Emergence %
3	30±1.7ab	58.89±1.11ab	5±2.89ab	71.67±1.67b	18.33±4.4a	70.0±7.6 b
6	35.56±1.11b	45.56±4.84C	11.67±1.67bc	55±2.89c	30±0.00b	70±0.00 b
9	56.67±3.85c	33.33±1.93D	20±0.00cd	40±2.89d	33.33±4.4 b	66.67±4.41b
12	62.22±2.94c	28.89±2.22D	23.33±4.41d	31.67±4.41e	51.67± 1.7 c	48.33±1.67 c
18	73.33±1.93d	15.56±2.94e	43.33±1.67e	18.33±1.67f	60±0.00 cd	40±0.00 c d
24	86.67±1.93e	6.67±3.33f	51.67±4.41e	6.67±1.67g	68.33±3.3 d	31.67±3.34 d
48	94.44±1.11f	0±00f	78.33±4.41f	0±0.0g	85± 2.9 e	15±2.89 e
Control	24.44±4.01a	64.44±1.11a	0±0.00a	80±2.89a	15±2.9a	85±2.89 a
LSD	15.3	15.6	18.016	15.4	17.67	22.1
F	105.3	82.2	78.86	130.9	72.2	40.9
P	0.000	0.00	0.000	0.000	0.000	0.000

As for pupae, N_2 gas revealed the highest percent of adult emergence (70%) after exposure of infested dates by pupae with 3h to nitrogen gas and the least percent of adult emergence 15% after exposure of infested dates by pupae with 48h.

The effect of nitrogen gas on mortality % and adult emergency % of immature stages of *S. paniceum* were shown in Table (2). Mortalities of immature stages of *S. paniceum* responding to modified atmospheres with nitrogen increased significantly (P < 0.01) with nitrogen exposure length as compared to the parallel control sample. Egg, larva, and pupa mortalities of *S. paniceum* were significantly increased F=88.3, P= 0.0001, F= 101.3, p=0.0001and F= 87.9, P= 0.0001, respectively by varying exposure periods to N_2 gas as compared to the parallel control sample. The highest mortality was (86.67%) achieved when date fruits infested with eggs and pupae of *S. paniceum* had been exposed to N_2 gas for 48h. Complete pest control was achieved when date fruits that were infested with larvae of *S. paniceum* had been exposed to N_2 gas for 24h. Furthermore, reductions in adult emergence were achieved from infested date fruits with eggs, larvae, and pupae significantly progressively with the increase of exposure period to N_2 gas F=20.9, P= 0.0001, F= 46.2, p=0.0001and F= 70.6, P= 0.0001, respectively as compared to the parallel control sample. Complete suppression of the adult emergence from the survivors of immature stages of *S. paniceum* was achieved when date fruits infested with larvae of *S. paniceum* had been exposed to N_2 gas for 24 h.

Table 2. Effect of nitrogen gas on mortality % and adult emergency % of immature stages of S. paniceum post exposure to nitrogen gas (98%) at different time of exposure.

Stage	Eggs		Larvae		Pupae	
Time (h)	Mortality %	Adults Emergence %	Mortality %	Adults Emergence %	Mortality %	Adults Emergence %
3	11.11± 0.33b	65.56±1.7 b	6.67± 0.33a	78.33± 1.8ab	13.33±0.33 b	86.67±0.33 a
6	21.11± 0.9c	51.11±1.5 bc	30±1.5 b	70± 1.5b	23.33± 0.33c	76.67 ± 0.9b
9	43.33 ± 0.33d	46.67±0.9 c	46.67± 0.33 c	48.33± 0.9c	28.33±0.7 c	71.67± 0.7b
12	56.67±0.33 e	38.89±0.9 c	65± 1.2 d	25±1.5 d	43.33±0.33 d	56.67±0.33 c
18	61.11±0.9ef	36.67±0.7 c	90± 1.00 e	3.33 ±0.33 e	48.33±0.7 d	51.67±0.7 c
24	68.89±0.7 f	26.67±1.2 d	100±0.00 e	0 ± 0.00e	66.67±0.9 e	33.33± 0.9d
48	86.67 ±0.9 g	16.67±0.33 d	100 ±0.00 e	0±0.00 e	86.67±0.9 f	13.33± 0.9e
Control	1.11±0.33a	93.33±0.33 a	3.33± 0.33 a	88.33± 0.9a	1.67±0.33a	95±0.00a
LSD	3.8	6.3	4.74	6.5	3.6	3.93
F	88.3	20.9	101.3	46.2	87.9	70.6
P	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001

The obtained results concluded that, factorial-analysis of general-trend between two-tested-pests; stages; and post-exposure-time to N_2 gas showed in Table (3). A highly significant effect on mortality and adult emergence percentages of *E. cautella* and *S. paniceum* was noted due to the time and the stages after exposure to the N_2 gas (F=93.94, p=0.0001, F=147.87, p=0.0001) and (F=86.24, p=0.0001 and F=52.61, p=0.0001) respectively. On the contrary, a non-significant effect was recorded on the mortality of *E. cautella* and *S. paniceum* due to the pest level (F=0.04, p=0.84). While a highly significant effect on adult emergence percent of *E. cautella* and *S. paniceum* was noted due to the same factor (F=34.22, p=0.0001).

Table 3. The factorial-analysis for general-trend between two pests-stages and inspection-times post-exposure of infested date-fruits with N2 gas

Factor	Level	Mortality	Adult Emergence
Pest	*Ephestia cautella*	10.75±1.66 a	9.25± 1.59 b
	Stegobium paniceum	10.65± 1.05 a	11.35± 1.29 a
F value		0.04	34.22
P value		0.84	0.0001
LSD		0.9688	0.71
Stage	Egg	15.25±1.194 a	11.79± 1.205 a
	Larvae	8.44± 0.849 b	7.71± 1.003 b
	Pupae	8.42± 0.784 b	11.39± 0.949 a
F value		86.24	52.61
P value		0.0001	0.0001
LSD		1.187	0.87
Time	0	1.94± 0.66 g	19.50±0.99 a
	3	3.5± 0.67 g	16.44± 0.60 b
	6	6.0± 0.65 f	13.89± 0.48 c
	9	9.3± 1.12 e	11.56±0.65 d
	12	12.1± 1.20 d	8.78± 0.65 e
	18	14.8± 1.21 c	6.39± 0.93 f
	24	17.3± 1.32 b	4.06± 0.77 g
	48	20.7± 1.18 a	1.78± 0.50 h
F value		93.94	147.87
P value		0.0001	0.0001
LSD		1.94	1.42

Time and pest level an influential factor that have a massive effect on the mortality percent and adult emergence from date fruits infested with eggs of *E. cautella* and *S. paniceum* after exposure to N_2 gas Table (4). The effect of highly-significant noted for both-times and pest-factors (F=192.5, p=0.0001 and F=98.01, p=0.0001) respectively.

The significant effects Determinations of exposure-times and tested-pests levels-factors on mortality% and adult-emergence from date fruits infested with larvae of *E. cautella* and *S. paniceum* after exposure to N_2 gas illustrated in (Table 5). The effect of high-significant noted for both-time and pest-factors (F=52.74, p=0.0001 and F=67.3, p=0.0001) respectively.

Table 4. Determinations of significant-effect of exposure-times and tested-pests levels factors on mortality% and adult emergence from date fruits infested with eggs of *Ephestia cautella* and *Stegobium paniceum* after exposure to N2 gas

Factor	Level	Mortality	Adult Emergence
Pest	*Ephestia cautella*	17.375± 1.55 a	9.5± 1.04 b
	Stegobium paniceum	13.125± 1.77 b	14.083± 1.42 a
F value		98.01	83.85
P value		0.0001	0.0001
LSD		0.868	1.012
Time	0	3.833±1.66 h	23.667± 1.99 a
	3	6.167±1.30 g	18.667± 0.61b
	6	8.50±1.02 f	14.500± 0.76 c
	9	15.00±1.13 e	12.00± 1.03 d
	12	17.833± 0.70 d	10.167± 0.75 d
	18	20.167± 0.87 c	7.833± 1.54 e
	24	23.33± 1.26 b	5.00± 1.44 f
	48	27.167± 0.72 a	2.500± 1.15 g
F value		192.5	98.77
P value		0.0001	0.0001
LSD		1.737	2.024

Table 5. Determinations of significant-effect of exposure-times and tested-pests levels factors on mortality% and adult emergence from date fruits infested with larvae of Ephestia cautella and Stegobium paniceum after exposure to N2 gas

Factor	Level	Mortality	Adults Emergence
Pest	*Ephestia cautella*	11.042± 1.6 a	7.5833± 1.16 a
	Stegobium paniceum	5.833 ± 1.57 b	7.833± 1.48 a
F value		67.3	0.26
P value		0.0001	0.0001
LSD		1.284	0.989
Time	0	0.330± 0.21e	16.83±0.60 a
	3	1.167± 0.31 e	15.00± 0.86 a
	6	4.167± 1.08 d	12.50± 0.99 b
	9	6.667± 1.20 cd	8.830± 0.60 c
	12	8.833± 1.97 c	5.667± 0.84 d
	18	13.33± 2.14 b	2.167± 0.70 e
	24	15.167± 2.20 b	0.667± 0.33 ef
	48	17.833± 1.05 a	0.00± 0.00 f
F value		52.74	90.96
P value		0.0001	0.0001
LSD		2.568	1.978

Moreover, both-factors (times and pest-levels) showed high-significant effects (F=148.91, p=0.0001 and F=16.53, p=0.0001), respectively on the mortality percent and adult emergence from date fruits infested with pupae of *E. cautella* and *S. paniceum* after exposure to N_2 gas Table (6).

The LT_{50} and LT_{95} values, together with their confidence limits, for immature stages of *E. cautella* and *S. paniceum* exposed to different duration periods with nitrogen gas, were shown in Table (7). The "LT_{50}" values resulted, *E. cautella* sensitivity "eggs and pupae" to modified atmospheres "Mas" contains "N_2" close to recorded of *S. paniceum* eggs and pupae. LT_{50} values were 22.33 and 8.76 h in larvae of *E. cautella* and *S. paniceum* respectively. While values LT_{95} indicated, *E. cautella* sensitivity "eggs and pupae" to "Mas" contains "N_2" close to half-recorded of *S. paniceum,* eggs and pupae. LT_{95} values were 134.78 and 29.15 h in larvae of *E. cautella* and *S. paniceum*, respectively.

Table 6. Determinations of significant-effect of exposure-times and tested-pests levels factors on mortality% and adult emergence from date fruits infested with pupae of Ephestia cautella and Stegobium paniceum after exposure to N2 gas

Factor	Level	Mortality	Adults Emergence
Pest	*Ephestia cautella*	9.0417± 0.99 a	10.667± 0.94 b
	Stegobium paniceum	7.7917± 1.11 b	12.123± 1.09 a
F value		16.53	16.41
P value		0.0002	0.0002
LSD		0.622	0.7281
Time	0	1.667±0.67 g	18.00±0.52 a
	3	3.167±0.48 f	15.667±1.02 b
	6	5.330±0.33 e	14.667±0.49 bc
	9	6.167±0.54 e	13.833±0.54 c
	12	9.50±0.43 d	10.50±0.43 d
	18	10.83±0.60 c	9.167±0.60 d
	24	13.5±0.50 b	6.50±0.50 e
	48	17.167± 0.48 a	2.833± 0.48 f
F value		148.91	100.07
P value		0.0001	0.0001
LSD		1.244	1.456

Table 7. The expected exposure-time (hour) caused mortality (50 and 90%) for E. cautella and S. paniceum eggs, larvae, and pupae post exposure of infested date fruits to nitrogen gas (98%) at different time of exposure.

Insect	Stage	LT_{50} (hour)			LT_{90} (hour)			Slope ± SE
		Value	Confidence limits		Value	Confidence limits		
			Lower	Upper		Lower	Upper	
E. cautella.	Eggs	12.2	9.5	16.3	34.3	29.2	66.4	2.9±0.23
	Larvae	22.33	19.7	25.79	90.6	69.2	130.3	2.11 ± 0.17
	Pupae	17.0	15.2	19.2	65.2	51.95	87.9	2.2 ± 0.17
S. paniceum	Eggs	12.3	10.97	13.9	55.3	44.4	73.3	1.97± 0.14
	Larvae	8.8	6.94	10.74	22.3	18.9	32.8	3.15± 0.23
	Pupae	15.12	13.4	17.27	72.9	56.6	101.19	1.88 ± 0.14

Estimation of some chemical compositions of date fruits post-exposure to N_2 gas after 3 days are shown in Table (8). Carbohydrate and iron percent were significantly different in treated date fruits; it was 50.2 and 14.13 mg%, respectively, compared with their compositions in control fruits (57.5 and 13.13). Meanwhile, the percentages of calcium and potassium of the date fruits exposed to N_2 gas after 3 days were no significant compared with control fruits.

Table 8. Biochemical analysis of date fruits exposed to nitrogen gas for 3 days.

Treatment	Carbohydrate (g/Kg)	Iron (%)	Calcium (Ca %)	Potassium (K %)
Nitrogen gas	$50.2±1.45^b$	$14.13±0.35^a$	$50.36±0.58^a$	$704±300^a$
Control	$57.5±1.26^a$	$13.13±0.29^b$	$55.23±1.63^a$	$980±11.55^a$
F value	13.31	8.18	20.86	0.97
LSD	6.09	0.94	5.05	600

***Mean ± stander error, means with same letter are no-significant different in same column.**

Discussion

The use of nitrogen has long been seen as a promising technique for the disinfestation of stored products. The term of "nitrogen," means the addition of nitrogen to a particular volume of air to lower the oxygen content (Navarro, 2006; Athanassiou *et al.,* 2017). As a result, death happens from an anoxic environment and dehydration. Thus, the most accurate expression can be "low oxygen" rather than "high nitrogen" (Navarro, 2006; Agrafioti *et al.,* 2022). Given that the percentages nitrogen and oxygen in the atmosphere are roughly 78% and 21%, respectively, and the increase in nitrogen will result in a proportional decrease in oxygen, which will cause hypoxia or anoxia (Mitcham, *et al.* 2006; Navarro, 2012 and Husain, *et al.* 2017).

The insect pests can be affected with "hypoxia" and "hypercapnia" (Cui *et al.* 2017). The toxicity to some pest stages achieved with some gas concentrations and exposure periods. O_2-decrease in insects causes inhibition of respiratory enzymes. Usually, nitrogen (N_2) is used to create a low-oxygen atmosphere (Adler *et al.,* 2000; Navarro, 2012).

Considering the insect species, and life stages evaluated here, nitrogen treatment proved to highly efficient against stored products pests. At this work, *E. elutella* and *S. paniceum* were utilized in this study since they are frequently found in date fruits warehouses in Egypt as well as other durable commodities of a similar nature (Buchelos 1980 and Athanassiou & Eliopoulos 2003, 2004). Substantial mortality rates were observed in both species and the life phases. We believe that our experimental design closely mimics actual storage facility settings.

Immature stages of *E. cautella* and *S. paniceum* were exposed to nitrogen gas 98% (Oxygen 1%) at different duration (3, 6, 12, 18, 24, and 48 h.). Our results revealed that the percentages of eggs, larvae, and pupae mortality were increased, and the adult emergence percentage was decreased for *E. cautella* and *S. paniceum* with increasing the exposure time to nitrogen gas 98% (Oxygen 1%). The discovery aligns with findings of Mbata *et al.* (2005), who suggested that exposing developmental stages of bruchids to 100% Co_2 requires longer exposure periods to achieve complete mortality. As also indicated by Soderstrom *et al.*, (1992) who mentioned that larval mortality in *T. castaneum* increased in conjunction with the increasing percentage of nitrogen in the environment, which significantly shortened the overall exposure length. This suggestion is also supported by the finding of Athanassiou *et al.* (2017) who showed that mortality of all life stages of various stored product insects shortened to 3 days when used commercial nitrogen chambers. Results also agreed with Ofuya and Reichmuth (2002) who reported that there was a complete control of all life stages of the bean bruchide *Callosobruchus maculatus* (Fabricius), after exposure to 1% nitrogen for 9 days.

In our results, two days exposure time were adequate to achieve complete inhibition of adult emergence of *E. cautella*. In agreement with that observation, Cheng *et al.* (2013) found that a gas-mixture of 2% O_2, 18% Co_2 and 80% N_2 had a substantial impact on the growth and survival of the cowpea bruchid, *C. maculatus*, during all developmental stages. While one day exposure was adequate to give complete mortality and preventation of adult emergence of *S. paniceum*. The same trend was identical with a pattern observed by Riudavets *et al.* (2010), who examined Co_2 efficacy at different-times and two-high-pressures, 15 and 20 bar, against various developmental stages of *O. surinamensis*, (*ryptolestes ferrugineus*, *Lasioderma serricorne*, *Sitophilus oryzae*, *Rhyzopertha dominica*, *Acanthoscelides obtectus*, *Ephestia kuehniella*, *Liposcelis bostrychophila* and *Tyrophagus putrescentiae* with standard food diets. According to their findings, all of the examined pest larvae killed in 60 minutes, while *E. kuehniella* larvae killed in 15 minutes at a pressure of 15 bars. The sensitivity of immature-stages of *E. cautella* and *S. paniceum* to different nitrogen gas treatments indicated that the sensitivity of the eggs and pupae of *E. cautella* to modified-atmospheres "MAs" contains N_2 was comparable to that seen for the eggs and pupae of *S. paniceum.* Consequent, it can be considered that *E. cautella* larva, most-tolerant-stage to "MAs" enriched with "N_2". In addition, in case of *S. paniceum*, the most tolerant stage to "MAs" enriched- ith N_2 is pupa. In addition, according to Zinhoum (2020), who found that exposing of *Corcyra cephalonica*'s immature stages to N_2 98% resulted in reductions in emerged adults from the egg, larval, and pupal stages by 7.89, 12.73, and 5.46%, respectively, after 2 hours and these rates increased gradually to reach 84.21, 89.09, and 83.64, respectively, after 96 hours. In contrast with the results of the present work, Hashem *et al.* (2012) recorded that, the most tolerant stage of *E. cautella* was the pupal stage when exposed to MAs containing 40%, 60% and 80% Co_2 in air at 27 °C. Also, Abd El-Aziz *et al.* (2014) found that the larval stage of *Plodia interpunctella* was more sensitive than the pupal stage due to the sclerotized cuticle of the pupa. The variation in susceptibility could be due to the use of different modified atmosphere gases. Tutuncu and Emekci (2019) found that eggs, older larvae, and pupae exhibited greater tolerance, whereas adults were more easily killed, and younger larvae were the most vulnerable.

Further research is needed to investigate the impact of increased nitrogen on the product itself, as the range of items that can be treated is vast and diverse, spanning from tobacco to dried fruit (de Sousa *et al.*, 2023). According to the present results, the chemical characteristics of treated date fruits with N_2 gas at 3 days of exposure were not significantly affected by the characteristics of control in the level of calcium and potassium. while a little effect was recorded in the level of carbohydrates and iron. Consistent with these results, Athanassiou *et al.*, (2017) observed that nitrogen did not affect the essential qualitative traits of the products. However, the presence of nitrogen in the environment significantly decreased the microbiological load of these products, including yeast and molds. Guarrasi *et al.*, (2014) reported that exposing fresh apples to modified atmosphere packaging (MAP) resulted in changes in the aromatic fingerprint of the fruit. Mattheis & Fellman (2000) observed that controlled atmospheres and MAP can decrease the levels of carbohydrates and titratable acids in fresh fruits and vegetables. Ahmed *et al.*, (2022) suggest that a combination of modified atmospheres (MAs) and half the recommended dose of phosphine can be effective in controlling insects in stored dried dates, while also potentially improving the quality of the fruit, even with short treatment times.

CONCLUSION

The modified atmosphere by using a high concentration of N_2 98% is an economically realistic and environmentally safe and clean method. Can use for controlling date fruits in storage as a safe method for humans and not negatively affect the quality of date fruits.

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تأثير الأجواء المعدلة بغاز النيتروجين في تطهير التمور المخزنة من الأطوار الغير مكتملة من *Ephestia cautella* و *Stegobium paniceum*

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الملخص

يمكن استخدام النتروجين كوسيلة بديلة للمكافحة الكيميائية لآفات المواد المخزونة. والهدف من هذه الدراسة تحديد تأثير الجو المعدل باستخدام تركيزات عالية من النتروجين في مكافحة الاطوار الغير كاملة من فراشة البلح العامري وخنفساء العقاقير كآفات رئيسية على محصول البلح وتأثيره علي الجودة. وقد استخدام تركيز 98% نتروجين (2% أوكسجين) على فترات تعريض مختلفة. وأوضحت النتائج ان البيض واليرقات والعذارى لكلا الحشرتين استجابت للجو المعدل باستخدام غاز النتروجين بزيادة فترات التعريض له. وكانت فترة يومين كافية لحدوث انعدام خروج فراشات من أطوار البيض واليرقات لدودة البلح العامرى المعاملة بالنتروجين. بينما في حالة يرقات خنفساء العقاقير حدث بعد التعريض لمدة 24 ساعة. كان عامل الوقت ومستوى الآفة عاملاً مؤثراً وكان لهما تأثير كبير على نسبة النفوق وظهور البالغين من ثمار التمر المصابة بالبيض واليرقات والعذارى من فراشة البلح العامري وخنفساء العقاقير بعد التعرض لغاز النيتروجين ولم يؤثر غاز النيتروجين علي خواص الجودة لثمار البلح المعاملة.