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Chemical quality parameters of three oilseeds influenced by both insect infestation and fumigation with phosphine in storage

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Abstract:

The purpose of the present study is to investigate the changes which occur for certain chemical quality parameters such as weight loss (WL), peroxide value (PV), free fatty acids (FFA) and protein content of some oilseeds affected by whether when their insect infestation in storage or its fumigation by phosphine gas. The results clearly showed that there was increase in WL and number of adult emergences with increasing of storage period. Also, results noticed that infested peanut seeds by *Ephestia cautella* (Walker) (Lepidoptera: Phycitidae) have higher PV, FFA and lower protein content, whilst, fumigated peanut seeds only significant higher protein content, but, did not induce any changes in PV and FFA. So, consider insect infestation had deleterious effect on the seeds and that phosphine fit as fumigant for peanut seeds as a result PV below the limit in the Codex standard of 10 mEqO2 kg-1 oil. Oppositely, sesame seeds, the results showed that fumigated and infested sesame seeds by *Oryzaephilus surinamensis* (L.) (Coleoptera: Silvanidae) have only significant higher PV and lower FFA and protein content which are consider indicator on quality deterioration of sesame seeds and phosphine unfit as fumigant for sesame seeds as a result PV higher of the limit in the Codex standard of 10 mEqO2 kg-1 oil. Also, fumigated and infested maize grains by *Rhyzopertha dominica* (F.) (Coleoptera: Bostrichidae), did not affect approximately all tested parameters with except protein content which significant increase in fumigated grains about infested and un-infested grains. So, phosphine fit as fumigant for maize grains.

Introduction

Oilseed crops are grown for their seeds purpose. Oilseeds are leading suppliers of superior quality and that of oilseeds add important nutritional value to the human diet due to high quality protein, vegetable oil (linoleic acid and oleic acid, Omega-6 fatty acids and Omega-3 fatty acids) and vitamin E (Quamruzzaman *et al.* , 2016). Oilseeds are considered the major sources for extracting edible oils and for applications in pharmaceutical, confectionary, perfumery and cosmetics industries. Of these oilseeds, Peanut, sesame, sunflower, maize, cotton, sunflower, rapeseed and olive are most oil crops cultivated in Egypt

and their oils are the most common healthy cooking oils used. The oil content of cereal grains as wheat is only 1- 2 % and that of oilseeds ranges from about 20 % for soybean to over 40 % for sunflowers and rapeseed (Canola) (Weiss, 2000). The quality of the vegetable oils is one of the most important factors that affect their acceptability and market value (O'Brien, 2004). Vegetable oils are recommended for healthy life because their high content of polyunsaturated fatty acids which decreases the risk of cardiovascular diseases *(*Ganesan *et al.*, 2018*).* The quality of oilseeds depends on many factors, particularly chemical deterioration which occurs during its exposure either to different insect infestations in storage or its treatment by inadequate approaches. Chemical properties such as acidity value, free-fatty acids value, peroxide value and vitamin E used to measuring biochemical deterioration and the stability of oils (Mousavi *et al.*, 2012 and Mbata, 1994). Oilseeds are rich in proteins and therefore are vulnerable to infestation by many stored products insects in storage. Of these insects, *Ephestia cautella* (Walker) (Lepidoptera: Phycitidae), *Oryzaephilus surinamensis* (L.) (Coleoptera: Silvanidae) and *Rhyzopertha dominica* (F.) (Coleoptera: Bostrichidae), resulting in weight loss and deterioration in oil quality and formation of toxins. The almond moth, *E. cautella* is one of the most important pests infesting stored peanut, grain, nuts, dried fruits and other many stored products (Boshra, 2007). The economic losses by this pest are due to reductions in quantity and quality of stored products (Hussain and Jafar, 1968**).** Saw-toothed grain beetle, *O. surinamensis* is one of the most common insect pests of grains and a variety of different stored products such as dried fruits ,oilseeds and has been found in all storage facilities (Beckel *et al*., 2007). They are two secondary pests in stored grain due to its inability to damage the whole grains. The lesser grain borer, *R. dominica* is a destructive insect pest of stored grains (Mayhew and Phillips, 1994). Both larvae and adults of this insect use their strong mandibles to attack whole, sound grains and cause extensive damage (Williams *et al*., 1981). The adults chew grains voraciously which not only causes weight loss but also reduces grains germination (Jilani *et al*., 1989). The purpose of the present study is to determine both effects of insect infestation and their control with phosphine gas on peroxide value (PV), free-fatty acids content (FFA) which are indices in measuring the oil quality in addition to protein content.

Materials and methods

1. Insect cultures:

The stocks of *O. surinamensis* used in these experiments were obtained from a stock culture maintained at the Stored Grain and Product Pests Department, Plant Protection Research Institute. It was reared on whole wheat flour for two months at 30 ±2^{0}C and 65 ±5 R.H. in continuous darkness. *R. dominica* was reared on sound maize grains under the same previous conditions. *E. cautella* was reared on peanut for two generations at 28 ± 2 ^{0}C and 70 ±5 RH.

2. Used oilseeds crops:

Peanut seeds (*Arachis hypogea*), sesame seeds, (*Sesamu indicum*) and maize grains (*Zea mays)* are most oilseeds crops cultivated in Egypt.

3. Experiments procedures:

3.1. Determination oilseeds damage induce with different insects infestation for four months storage periods:

Hundred grams of each type were put in glass jars (Ca: 0.5 L. each), ten pairs of *O. surinamensis and R. dominica* adults (15 days old) were

introduced separately in jars containing sesame seeds and maize grains, respectively. Peanut seeds infested by three pairs of *E. cautella* moths (0-24 h. old). Jars were left in the laboratory into incubator for two and four months (30 ± 2^0C and 65±5 RH.) for all previously mentioned insect species. The previous design was replicated three times to each insect species and two periods of storage. At the end of each storage period, the insects had been removed and were counted; the seeds samples were reweighed to determine weight loss, then samples analyzed to assessment effects of insect infestation on peroxide value (PV), free-fatty acids (FFA) as indicator on the products quality according to Mbata (1994) and protein. Weight loss (%) was calculated according to the equation of Khare and Johari (1984).

Weight loss (%) = (initial dry weight– final dry weight) / initial dry weight x 100

3.2. Determination oilseeds damage treated with phosphine fumigant at recommended dose (15 bellets /m^3):

The experiments were conducted using jute bags: (Ca: 0.5 kg each): Four jute bags contained 25 g of peanut seeds were artificially infested by 25 larvae (4^{th} instar) of *E. cautella*. In case of sesame seeds, four jute bags contained 25 g sesame seeds infested artificially by 25 adults of *O. surinamensis*. Also, four jute bags contained 25 g of maize infested by 25 adults of *R. dominica*. The bags were directly closed and exposed to phosphine gas at recommended dose (15 bellets /m^3 or /ton and 4 days exposure periods) inside a plastic container (16-liter capacity) as fumigation chambers. Fumigation chambers were sealed by paraffin and adhesive tape. Four untreated jute bags were kept as control for each insect species. Jut bags for each replicate were observed after treatments to count numbers of alive and dead and calculate mortality percent that was corrected according to Abbott's formula (1925), then, the seeds samples were analyzed to assessment effects fumigation with phosphine on PV, FFA in addition to protein content.

4. Chemical properties analysis of infested and fumigated oilseeds:

Peroxide value and free fatty acids are estimated using the method described by Sadasivam and Manickam (1991). Total Protein content of seeds samples was estimated by the method of Bradford (1976). Protein content was expressed as µg protein/g weight.

5. Statistical analysis of the obtained data:

The data were statistically analyzed using Costat Software Program (1985). Least Significant Differences test (LSD) was used for comparison between treatment means at 5 % level of probability according to Snedecor and Chachran (1981).

Results and discussion

1. Determination oilseeds damage induce with different insects infestation for two and four months storage periods:

Two storage periods and different oilseeds were investigated to determine weight loss of oilseeds due to different insect infestations at 2 and 4 months storage after infestation as well as study certain the changes which occur of quality parameters such as PV, FFA and protein of some oilseeds affected whether when their insect infestation during storage and or their fumigation by phosphine gas. The most important resul**ts** can be summarized as follows. The data presented in Table (1) regarding peanut seeds infested with *E. cautella* during two observation periods. It was revealed that there were great variations in weight loss among infested and un-infested seeds. The weight loss % was significantly higher in infested peanut seeds (7.47 and 28.99

%) compared with un-infested peanut (0.8 and 1.2 %) at 2 and 4 months storage periods because cumulative number of *E. cautella* progeny, since, the means of emerged adult were 61.25 and 356.5 insects. These results are supported by the findings of Mali and Satyavir (2005) who observed that the insect damage increased by the storage period. The similar results were observed in case of other seeds. The highest weight loss of sesame seeds was recorded in infested seeds with *O. surinamensis* whether at 2 or 4 months, since, it recorded 2.57 and 4.1 % at 2 or 4 months, resp. compared to 0.3 and 0.57 % for control with significant differences between infested and un-infested seeds. This is variation in loss correlated well with cumulative number of *O. surinamensis* progeny, where, the means of emerged adults were 39.5 and 62 insects at 2 or 4 months for infested seeds, resp. Similarly, the maximum weight loss of maize grains was recorded in infested grains with *R. dominica* either at 2 or 4 months, where, it recorded 4.65, and 6.16 % at 2 or 4 months resp. compared with 0.4 and 0.7 % for control at 2 or 4 months, resp. Also, loss correlated with cumulative number of *R. dominica* progeny, it was recorded 48.5 and 79.25 insects at 2 or 4 months, resp. but no adult emergence in all un-infested seeds (Control).

Table (1): Weight loss and cumulative number progenies of peanut, sesame and maize seeds affected by different insect infestation after 2 and 4 months of infestation

Treatments	After 2 months		After 4 months	
	Loss %	Cumulative no. of progenies	Loss %	Cumulative no. of progenies
Un-infested Peanut	0.8 ± 0.07 b	0.0 ± 0.0 B	1.2± 0.13 b	0.0 ± 0.0 b
Peanut infested with *E. c*.	7.47 ± 0.29 a	61.25±4.25 a	28.99± 2.44 a	356.5± 15.55 a
LSD 0.05	0.745	10.39	5.96	20.04
Un-infested sesame	0.3 ± 0.04 b	0.0 ± 0.0 B	0.57 ± 0.08 b	0.0 ± 0.0 B
Sesame infested with *O. s*.	2.57 ± 0.41 a	39.5 ± 3.18 A	4.1 ± 0.54 a	62 ± 4.83 a
LSD 0.05	1.01	7.77	1.33	11.82
Un-infested maize	0.4 ± 0.05 b	0.0 ± 0.0 B	0.7 ± 0.07 b	0.0 ± 0.0 B
Maize infested with *R. d.*	4.65 ± 0.42 a	48.5 ± 5.04 a	6.16± 0.13 a	79.25 ± 1.89 a
LSD 0.05	0.74	8.28	0.37	4.62

Lack of data on insect infestation, control methods and pesticides residues in oilseeds have been highlighted. This is in line with the findings of Weiss (1983) who stated that losses in stored sesame seeds and cake are said to be substantial although there is little published information to back up this claim. Srivastava (1970) reported that loss in sesame stored in Uttar Pradesh, India, caused mainly by *Tribolium castaneum* (Herbst) (Coleoptera: Tenebrionidae) and *Corcyra cephalonica* (Stainton) (Lepidoptera: Pyralidae) have reportedly reached 4.4 %. Gebremichael (2017) showed that weight loss of sesame seeds due to *Plodia interpunctella* was 17.8±5.5%. Kurdikeri *et al.* (1994) found that percentage seed damage and weight loss due to *R. dominica* (F.) infestation increased markedly with the increasing in storage period in all the maize hybrids. The results of Metwalley, *et al.* (2007) showed significant reduction in date weight as storage period increased resulted from infestation by *E. cautella*, and *O. surinamensis*.

2. Effect of *Ephestia cautella* infestation and phosphine gas on important nutrient elements composition of peanut seeds:

The results obtained presented in Table (2) shows the effect of peanut seeds infestation by *E. cautella* and fumigated with phosphine on important nutrient composition. The results showed that peanut seeds infested by *E. cautella* within 4 months storage had significant effect on all tested parameters, whereas, peanut seeds fumigated with phosphine did not significant effect on all tested parameters with exception protein content which increased compared to control. This is because there were significant differences between infested, fumigated and un-infested peanut seeds (Control). In case of PV, it appears that the highest PV was 8.73 mEqO2/kg in infested peanut seeds at 4 months of storage, but far below the limit in the Codex standard of 10 mEqO2 kg-1 oil, then significantly decreased to reach to 5.53 and 5.23 mEqO2/kg in fumigated peanut seeds and un-infested seeds (control) with significant differences between them. Similar trend was observed in case of FFA where, it was noticed that highest FFA contents was 7.97 mg triolein % in infested peanut seeds. Whereas, FFA contents in peanut seeds fumigated with phosphine not affected compared with un-fumigated peanut seeds (Control), where, it were 4.63 and 3.95, resp. Protein content of stored peanut seeds for 4 months of storage was affected by both insect infestation and phosphine compared with (Control). Insect infestation for peanut by *E. cautella* caused significant reduction in protein contents, while, phosphine caused increased in protein contents, since, protein contents was 21.6 and 39.4 mg % in infested and fumigated peanut seeds by *E. cautella*, with significant differences, compared with control which recorded 31.63 mg % with significant differences. Mortality % of *E. cautella* presented on peanut seeds due to fumigation with phosphine (As recommended dose) was 100 % compared with un-fumigated *E. cautella*, which recorded 8 % mortality. Our results revealed that there is significant increase in FFA which considered as indicator to peanut seeds deterioration in storage by *E. cautella* infestation. These results were confirmed by results of Pomeranz (1982) reported that increase in fat acidity value are known to reflect product deterioration. Mbata (1994) showed that infestation of bambarra groundnuts (*Vigna subterranea*) with *Callosobruchus subinnotatus* (Pic.) (Coleoptera: Chrysomelidae) increased free fatty acids and peroxides, which

are indices in measuring biochemical deterioration. Bamaiyi *et al*. (2007) who reported that qualitative deterioration of cowpea grains due to cowpea infestation by *Callosobruchus maculatus* (F.) (Coleoptera: Chrysomelidae). Babarinde *et al.* (2013) stated that voracious feeding on sound grains by *S. zeamais* causes product quality loss through an increase in free fatty acids. But, in case of fumigation with phosphine, important nutrient composition of peanut seeds did not significant affect with phosphine. Current work showed that protein content increased when the level of insects rose.

Table (2): Change in important nutrient elements quality of peanut seeds as affected either by *Ephestia cautella* infestation or fumigation by phosphine gas.

Tested parameters Treatments	**Peroxide value** (mEqO2/kg)	**Free fatty acid** *(mg triolein %)*	**Total protein** mg %	**Mortality %**
Infested seeds	8.73 ± 0.27 A	7.97±0.43 A	21.6 ±0.86 C	--
Fumigated seeds	5.53 ± 0.24 B	4.63±0.19 B	39.4 ± 1.97 a	100 A
Control seeds	5.23±0.18 B	3.95±0.1 B	31.63±1.45 b	8 B
LSD 0.05	0.80	0.96	5.18	

This confirms by Sudesh *et al*. (1996) found that infestation of maize grains with single or mixed populations of *R. dominica* resulted in substantial reductions in total lipids contents, In contrast, other results were observed by Siddhuraju *et al*. (2002) reported that gamma irradiation did not induce any changes in protein and lipids contents of soybean and groundnut.

3. Effect of *Oryzaephilus surinamensis* infestation and phosphine gas on important nutrient elements composition of sesame seeds:

The results of the important element composition of the sesame seeds after both infestation by *O. surinamensis* and fumigation with phosphine gas are presented in Table (3).

Table (3): Change in important nutrient elements quality of sesame seeds as affected either by *Oryzaephilus surinamensis* infestation or fumigation by phosphine .

.Tested parameters Treatments	**Peroxide value (mEqO2/kg)**	**Free fatty acid (mg triolein %)**	**Total protein mg %**	**Mortality %**
Infested seeds	10.27 ± 0.15 a	2.89± 0.07 b	12.43±0.76 c	--
Fumigated seeds	10.57± 0.38 a	3.2± 0.08ab	18.3±0.66 b	100 a
Control seeds	4.1 ± 0.12b	3.33± 0.12 a	23± 0.95 a	5 b
LSD 0.05	0.85	0.32	3.56	

Results noticed that PV of infested and fumigated sesame seeds were significantly higher than those of the un-infested sesame seeds (control), it was recorded 10.27 and 10.57 for infested and fumigated sesame seeds, resp. without significantly differences and it is higher the limit in the Codex standard of 10 mEqO2 kg-1 oil (Alimentarius, 1999), then significant reduced to 4.1 for control. Consequently, become seeds unacceptable as a result for quality deterioration and that phosphine unfit as fumigant for sesame seeds. As well, FFA was 2.89 and 3.2 *mg triolein %* for infested and fumigated sesame seeds, resp. then significant increased to reach to 3.33 for un-infested seeds (Control). The results are in agree with Semple (1986) reported that changes in quality of the grain during storage are often exacerbated by the insect infestation. Protein content, data revealed that infested sesame seeds with *O. surinamensis* had the lower protein content than fumigated and un-infested sesame seeds. It was recorded 12.43,

18.3 and 23 for infested, fumigated and un-infested seeds, resp. with significant differences between them. Complete mortality of *O. surinamensis* rearing on sesame seeds due to fumigation with phosphine compared with un-fumigated *O. surinamensis* which recorded 5 % mortality. These results are further supported by the findings of Lamboni and Hell (2009) found a reduction in the amount of proteins in stored grain can occur as a result of insect infestation. Akintunde (2012) reported that *C. maculatus* reduced the content of lipids of beans by over 50 %. Babarinde *et al.* (2010) reported that the proximate composition of the chips affected with infestation of plantain chips by *Tribolium castaneum*. The results are presented of Chattha *et al.* (2016) demonstrated that fat and protein loss of stored grain may be due to insect infestation which enhance the activity of proteolytic enzymes. *O. surinamensis* feeding activities could finger as a possible reason for this depletion. This is in consonant with the findings of El-Badawy *et al.* (2013) significant decrease in the total lipid and protein contents were observed for irradiated peanut seeds and dry bean seeds.

4. Effect of *Rhyzopertha dominica* infestation and phosphine gas on important nutrient elements composition of maize grains:

Data in Table (4) show effect of maize grains infestation by *R. dominica* and their fumigated with phosphine on the important element composition. Results noticed that PV was not affected either with insect infestation or phosphine; it recorded 0.69, 0.75 and 0.79 for infested, fumigated and un-infested sesame seeds without significantly differences. Whereas FFA and protein content were only significant affect in maize grains treated with phosphine, it was 2.25 and 7.97 for FFA and protein content, resp. compared to 2.19 and 5.93, resp. for control, but in case infested maize grains not significant varies with un-infested maize grains, since it recorded 2.07 and 5.57 for FFA and protein content, resp.

Table (4) Change in important nutrient elements quality of maize seeds as affected either by *Rhyzopertha dominica* infestation or fumigation by phosphine gas.

Tested parameters Treatments	Peroxide value (mEqO2/k)	Free fatty acid (mg triolein %)	Total protein mg %	Mortality %
Infested seeds	0.69±0.05 a	2.07±0.04 b	5.57±0.17 b	--
Fumigated seeds	0.75±0.03 a	2.25±0.02 a	7.97±0.32 a	100
Control seeds	0.79±0.06 a	2.19±0.06 ab	5.93±0.2 b	10
LSD 0.05	0.16	0.14	0.81	

Also, complete mortality of *R. dominica* reared on maize seeds due to phosphine compared with un-fumigated *R. dominica*, it was recorded 10 % mortality. These results in agreement with Muangkaeo *et al*. (2005) found a decrease in fat content of grain during storage. Other results were observed by Siddhuraju *et al*., (2002) reported that protein and lipids contents in groundnut and soybean did not affect with gamma irradiation treatment. Bashir *et al*. (2013**)** reported that the deterioration of nutritional and rheological properties of the stored wheat mainly occurs due to insect infestation after six months of storage. Finally, previous reports confirmed the impact of several factors on changes in important nutrient quality of stored grains such as the effect of insect infestation and storage periods (Bamaiyi *et al*., 2007 and Babarinde *et al.,* 2010), product types (Babarinde, 2013), temperature and relative humidity (White and Jayas, 1989), storage methods (Chattha *et al.*, 2016)

and irradiation (El-Badawy *et al.*, 2013). But, investigation insect infestation and phosphine effects on important nutrient in oilseeds were rare or not found.

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