Effect of Insect Infestation and Storage on Lipids of Cereal Grains

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Insect infestation of wheat, maize, and sorghum grains caused by *Trogoderma granarium* Everts and *Rhyzopertha dominica* Fabricius singly or in mixed populations resulted in substantial reductions in the contents of total lipids, phospholipids, galactolipids, and polar and nonpolar lipids. The reduction was significant ($P < 0.05$) at 50 and 75% infestations. Phospholipids in wheat and galactolipids in maize and sorghum were more affected as compared to other lipid classes. Losses of lipids showed significant ($P < 0.05$) and negative correlations with the levels of insect infestations. *T. granarium* was comparatively more destructive than *R. dominica* because of variation in the distribution pattern of lipids in seed components and feeding habits of insects. Storage of three cereal grains for 1, 2, and 4 months had no significant effect on total lipids and other classes of lipids.

Keywords: *Lipids; cereals; insect infestation; storage*

INTRODUCTION

Cereal grains such as wheat, maize, and sorghum are the principal and inexpensive sources of dietary carbohydrates, proteins, and minerals in India and some other developing countries. Besides these reasons, they also meet the requirement of lipids partly because of their bulk consumption. These cereal grains are attacked by several insect pests in storage. Among these, *Rhyzopertha dominica* Fabricius and *Trogoderma granarium* Everts are the most serious pests in tropical and subtropical regions of Asia and Africa (Atwal, 1976; Viljoen, 1990). They not only cause postharvest losses in terms of quantity but also affect quality through depletion of specific nutrients (Girish *et al.*, 1975; Swaminathan, 1977; Jood, 1990; Jood and Kapoor, 1992) and contamination with uric acid (Swaminathan, 1977; Jood and Kapoor, 1993).

During storage, some insect pests like *Sitotroga cerealella* Oliver in maize (Pandey and Pandey, 1977), *Sitophilus oryzae* L. in rice, wheat, and sorghum (Nirmala and Kokilavani, 1980; Sudhakar and Pandey, 1981, 1987), and *Tribolium castaneum* Herbst. in sorghum (Nirmala and Kokilavani, 1980) have been reported to decrease oil content of grains. But information is meager with regard to *R. dominica* and *T. granarium*. To date, there is no research report on the effect of insect infestation on quality of lipid classes *viz.* galactolipids, phospholipids, and polar and nonpolar lipids in wheat, maize, and sorghum grains. These lipids in the human body have three roles. (1) In adipose tissue, they form the chief store of energy. (2) In all tissues, they are a main part of the structure of cell membranes. (3) They are the precursors from which many hormones are made (Passmore and Eastwood, 1986).

Information is also lacking on the effect of storage of cereal grains in insect free conditions on the lipid contents. However, storage of wheat flour has been reported to decrease lipid content (Premavalli *et al.*, 1973; Warwick *et al.*, 1979). This paper reports the effect of different levels of insect infestation (25, 50, and 75%) caused by *R. dominica* and *T. granarium* and different storage periods (1, 2, and 4 months) on total lipids and lipid classes of wheat, maize, and sorghum grains.

MATERIALS AND METHODS

Preparation of Grain Samples and Storage. Mass cultures of two insect species, *T. granarium* and *R. dominica*, were maintained in the ambient laboratory temperature (28−39 °C) and relative humidity (60−90%) conditions. Healthy grains of commercial varieties of wheat, maize, and sorghum apparently free from insect infestation were subjected to phosphine (aluminum phosphide) fumigation to eliminate any undetected populations of insects. After fumigation, the grains were put in glass jars (20 × 15 cm), each containing 1.5 kg. The jars were covered with muslin cloth held by elastic bands and placed in the laboratory for conditioning. On the 10th day, moisture levels of the grains ranged from 10 to 11% which is suitable for multiplication of both insects (Pingale and Girish, 1967). The jars of each food grain were subdivided into three sets.

In the first set of each grain, 60 larvae of *T. granarium* were released into each jar to obtain three levels of infestation (25, 50, and 75% in three replicates). Larvae were used because of their high grain-damaging potential; the adults of *T. granarium* do not feed on grains and as such are harmless. In the second set, 60 adults of *R. dominica* were released similarly, while in the third set, mixed populations (30 larvae of *T. granarium* plus 30 adults of *R. dominica*) were released to achieve the desired levels of infestation. Adults of *R. dominica* are more harmful than larvae. Hence, adults were preferred over larvae to create infestations in the grains. To record infestation levels, grain samples (500 grains/jar) were inspected twice a week after the release of insects and the grains which showed signs of insect damage were considered to be infested. In each set, controls (jars without insects) were stored similarly to study the effect of storage periods. Storage for 1, 2, and 4 months was necessary to obtain 25, 50, and 75% levels of grain infestation, respectively, under ambient laboratory temperature (28−39 °C) and relative humidity (60−90%). When the desired levels of infestation were approached, jars were immediately disinfested with aluminum phosphide fumigation to prevent further damage. Grains were cleaned and ground in a Cyclotec mill to pass a 60 mesh sieve and then stored in air tight polyethylene bottles for further analysis.

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Table 1. Effect of Insect Infestation on Total Lipids and Lipid Classes of Wheat Grains (Grams per 100 g, on Dry Matter Basis)[a]

insect species	infestation level (%)	total lipids	phospholipids	galactolipids	polar lipids	nonpolar lipids
T. granarium	25	1.75 ± 0.01 (7)[b]	0.16 ± 0.00 (11)	0.30 ± 0.01 (12)	0.52 ± 0.01 (12)	1.22 ± 0.03 (5)
	50	1.65 ± 0.00 (13)	0.14 ± 0.02 (22)	0.27 ± 0.02 (21)	0.48 ± 0.02 (20)	1.15 ± 0.04 (10)
	75	1.45 ± 0.00 (23)	0.10 ± 0.00 (44)	0.23 ± 0.01 (32)	0.39 ± 0.01 (34)	1.05 ± 0.02 (18)
	mean	1.62	0.13	0.27	0.46	1.14
R. dominica	25	1.89 ± 0.01 (0)	0.18 ± 0.00 (0)	0.34 ± 0.01 (0)	0.59 ± 0.02 (0)	1.28 ± 0.02 (0)
	50	1.80 ± 0.02 (5)	0.17 ± 0.01 (6)	0.32 ± 0.02 (6)	0.57 ± 0.03 (3)	1.23 ± 0.04 (4)
	75	1.68 ± 0.03 (11)	0.15 ± 0.02 (17)	0.29 ± 0.00 (15)	0.52 ± 0.01 (12)	1.16 ± 0.05 (9)
	mean	1.79	0.17	0.32	0.56	1.22
T. granarium + *R. dominica*	25	1.85 ± 0.02 (2)	0.17 ± 0.01 (6)	0.32 ± 0.02 (6)	0.57 ± 0.03 (6)	1.27 ± 0.02 (1)
	50	1.75 ± 0.01 (7)	0.16 ± 0.00 (11)	0.30 ± 0.01 (12)	0.52 ± 0.01 (12)	1.23 ± 0.04 (4)
	75	1.65 ± 0.00 (13)	0.14 ± 0.02 (22)	0.28 ± 0.00 (18)	0.48 ± 0.02 (20)	1.15 ± 0.04 (10)
	mean	1.75	0.16	0.30	0.52	1.21
control	0	1.89 ± 0.01	0.18 ± 0.00	0.34 ± 0.01	0.59 ± 0.01	1.28 ± 0.02
insect species	SEM	0.03	0.02	0.03	0.02	0.02
	CD ($P < 0.05$)	NS	NS	NS	NS	NS
infestation level	SEM	0.02	0.02	0.02	0.01	0.02
	CD ($P < 0.05$)	0.06	0.06	0.06	0.03	0.06
insect species ×	SEM	0.04	0.03	0.03	0.02	0.04
infestation level	CD ($P < 0.05$)	NS	NS	NS	NS	NS

[a] Values are means ± SD of six independent determinations. SD denotes standard deviation. SEM denotes the standard error of the mean across all treatments. CD denotes critical difference. Differences of two means between the insect species/infestation level exceeding this level are significant. [b] Figures in parentheses are percent decrease over control.

Table 2. Effect of Insect Infestation on Total Lipids and Lipid Classes of Maize Grains (Grams per 100 g, on Dry Matter Basis)[a]

insect species	infestation level (%)	total lipids	phospholipids	galactolipids	polar lipids	nonpolar lipids
T. granarium	25	3.13 ± 0.02 (4)[b]	0.45 ± 0.02 (6)	0.29 ± 0.01 (7)	0.79 ± 0.03 (6)	2.32 ± 0.05 (5)
	50	3.00 ± 0.01 (8)	0.41 ± 0.01 (15)	0.23 ± 0.01 (26)	0.68 ± 0.02 (19)	2.29 ± 0.08 (6)
	75	2.58 ± 0.02 (21)	0.32 ± 0.02 (33)	0.18 ± 0.00 (42)	0.59 ± 0.01 (30)	1.99 ± 0.06 (18)
	mean	2.90	0.39	0.23	0.69	2.20
R. dominica	25	3.16 ± 0.02 (3)	0.46 ± 0.01 (4)	0.30 ± 0.01 (3)	0.82 ± 0.04 (2)	2.34 ± 0.05 (4)
	50	3.06 ± 0.02 (6)	0.42 ± 0.02 (13)	0.26 ± 0.00 (16)	0.76 ± 0.01 (10)	2.32 ± 0.06 (5)
	75	2.94 ± 0.01 (10)	0.40 ± 0.01 (17)	0.22 ± 0.01 (29)	0.68 ± 0.02 (19)	2.26 ± 0.07 (7)
	mean	3.05	0.43	0.26	0.75	2.31
T. granarium + *R. dominica*	25	3.16 ± 0.02 (3)	0.46 ± 0.01 (4)	0.29 ± 0.01 (7)	0.80 ± 0.03 (3)	2.34 ± 0.05 (4)
	50	3.07 ± 0.03 (6)	0.42 ± 0.02 (13)	0.25 ± 0.00 (20)	0.75 ± 0.02 (11)	2.29 ± 0.08 (6)
	75	2.88 ± 0.01 (11)	0.38 ± 0.01 (21)	0.23 ± 0.01 (26)	0.67 ± 0.04 (20)	2.20 ± 0.06 (10)
	mean	3.04	0.42	0.26	0.74	2.28
control	0	3.25 ± 0.06	0.48 ± 0.01	0.31 ± 0.01	0.84 ± 0.06	2.43 ± 0.08
insect species	SEM	0.03	0.04	0.03	0.02	0.04
	CD ($P < 0.05$)	NS	NS	NS	NS	NS
infestation level	SEM	0.02	0.03	0.03	0.03	0.03
	CD ($P < 0.05$)	0.06	0.09	0.09	0.09	0.09
insect species ×	SEM	0.03	0.05	0.04	0.05	0.05
infestation level	CP ($P < 0.05$)	NS	NS	NS	NS	NS

[a] Values are means ± SD of six independent determinations. SD denotes standard deviation. SEM denotes the standard error of the mean across all treatments. CD denotes critical difference. Differences of two means between the insect species/infestation level exceeding this level are significant. [b] Figures in parentheses are percent decrease over control.

Lipid Estimation. The lipids were extracted by the method of Huber and Newman (1975), and the amounts of total lipids present in samples were determined gravimetrically. The quantity of phospholipids present in the lipid sample was determined by measuring lipid phosphorus (Broekhuyse, 1968). The amount of galactolipids was determined on the basis of galactose content of the lipids. Therefore, galactolipids were first hydrolyzed to give free hexose by the method of Joseph (1954) and then estimated according to the procedure described by Trevelyan and Harrison (1952). Nonpolar and polar lipids were determined by the method of Nichols (1964).

Statistical Analysis. The data were subjected to analysis of variance (ANOVA) in a completely randomized design to determine the significant differences among various treatments. Correlation coefficients between levels of insect infestation and levels of the lipid contents of three cereal grains were derived by using standard product moment correlation coefficient formulae (Snedecor and Cochran, 1968).

RESULTS

Effect of Insect Infestation. There was a significant ($P < 0.05$) decrease in total lipids and various classes of lipids of wheat with the increase in insect infestation levels (Table 1). The decrease in total lipids (7−23%), phospholipids (11−44%), galactolipids (12−32%), polar lipids (12−34%), and nonpolar lipids (5−18%) at different levels of infestation due to *T. granarium* was higher as compared to the decrease of *R. dominica* samples showing 0−11% total lipids, 0−17% phospholipids, 0−15% galactolipids, 0−12% polar lipids, and 0−9% nonpolar lipids. The mixed population of both insect species produced intermediate losses. Losses in phospholipids were higher as compared to the losses of other classes of lipids.

Maize grains also manifested a significant decrease

Table 3. Effect of Insect Infestation on Total Lipids and Lipid Classes of Sorghum Grains (Grams per 100 g, on Dry Matter Basis)[a]

insect species	infestation level (%)	total lipids	phospholipids	galactolipids	polar lipids	nonpolar lipids
T. granarium	25	1.80 ± 0.03 (3)[b]	0.24 ± 0.00 (17)	0.11 ± 0.00 (27)	0.42 ± 0.01 (16)	1.35 ± 0.01 (2)
	50	1.65 ± 0.02 (11)	0.20 ± 0.00 (31)	0.08 ± 0.00 (47)	0.34 ± 0.02 (32)	1.31 ± 0.00 (4)
	75	1.45 ± 0.01 (22)	0.17 ± 0.00 (41)	0.07 ± 0.00 (53)	0.30 ± 0.00 (40)	1.14 ± 0.02 (17)
	mean	1.63	0.20	0.09	0.35	1.27
R. dominica	25	1.82 ± 0.03 (2)	0.26 ± 0.01 (10)	0.13 ± 0.01 (13)	0.46 ± 0.02 (8)	1.36 ± 0.00 (1)
	50	1.78 ± 0.01 (4)	0.23 ± 0.00 (21)	0.11 ± 0.00 (27)	0.42 ± 0.01 (16)	1.32 ± 0.01 (4)
	75	1.66 ± 0.01 (10)	0.20 ± 0.00 (31)	0.09 ± 0.00 (40)	0.39 ± 0.00 (22)	1.25 ± 0.00 (9)
	mean	1.75	0.23	0.11	0.42	1.31
T. granarium + *R. dominica*	25	1.81 ± 0.02 (2)	0.25 ± 0.02 (14)	0.12 ± 0.00 (20)	0.44 ± 0.01 (12)	1.35 ± 0.01 (2)
	50	1.73 ± 0.00 (7)	0.21 ± 0.00 (28)	0.10 ± 0.00 (33)	0.39 ± 0.00 (22)	1.32 ± 0.01 (4)
	75	1.60 ± 0.01 (14)	0.19 ± 0.01 (35)	0.09 ± 0.00 (40)	0.34 ± 0.01 (32)	1.19 ± 0.00 (13)
	mean	1.71	0.21	0.10	0.39	1.29
control	0	1.85 ± 0.02	0.29 ± 0.03	0.15 ± 0.01	0.50 ± 0.02	1.37 ± 0.03
insect species	SEM	0.03	0.02	0.01	0.01	0.02
	CD ($P < 0.05$)	NS	NS	NS	NS	NS
infestation level	SEM	0.03	0.02	0.01	0.01	0.02
	CD ($P < 0.05$)	0.09	0.06	0.03	0.03	0.06
insect species × infestation level	SEM	0.04	0.03	0.02	0.02	0.03
	CD ($P < 0.05$)	NS	NS	NS	NS	NS

[a] Values are means ± SD of six independent determinations. SD denotes standard deviation. SEM denotes the standard error of the mean across all treatments. CD denotes critical difference. Differences of two means between the insect species/infestation level exceeding this level are significant. [b] Figures in parentheses are percent decrease over control.

Table 4. Correlation between Lipids of Cereal Grains and Infestation of *T. granarium* and *R. dominica*

	correlation coefficient (r) values					
	level of infestation of *T. granarium*			level of infestation of *R. dominica*		
lipids	wheat	maize	sorghum	wheat	maize	sorghum
total lipids	−0.985[a]	−0.948	−0.964[a]	−0.934	−0.998[a]	−0.944
phospholipids	−0.985[a]	−0.966[a]	−0.995[a]	−0.983[a]	−0.990[a]	−1.00[a]
galactolipids	−0.998[a]	−0.983[a]	−0.981[a]	−0.924	−0.971[a]	−1.00[a]
polar lipids	−0.990[a]	−0.991[a]	−0.990[a]	−0.895	−0.970[a]	−0.996[a]
nonpolar lipids	−0.992[a]	−0.956[a]	−0.900	−0.931	−0.941	−0.948

[a] Significant at 5%.

Table 5. Effect of Storage on Total Lipids and Lipid Classes of Wheat, Maize, and Sorghum Grains (Grams per 100 g, on Dry Matter Basis)[a]

cereals	storage period (months)	total lipids	phospholipids	galactolipids	polar lipids	nonpolar lipids
wheat	0	1.89 ± 0.01	0.18 ± 0.00	0.34 ± 0.01	0.59 ± 0.01	1.28 ± 0.02
	1	1.88 ± 0.02	0.18 ± 0.00	0.34 ± 0.01	0.58 ± 0.01	1.28 ± 0.01
	2	1.86 ± 0.01	0.18 ± 0.00	0.33 ± 0.00	0.57 ± 0.02	1.29 ± 0.01
	4	1.85 ± 0.01	0.17 ± 0.01	0.32 ± 0.01	0.55 ± 0.01	1.30 ± 0.02
	mean	1.87	0.18	0.33	0.57	1.29
maize	0	3.25 ± 0.02	0.48 ± 0.01	0.31 ± 0.00	0.84 ± 0.01	2.38 ± 0.04
	1	3.23 ± 0.01	0.48 ± 0.00	0.30 ± 0.00	0.83 ± 0.02	2.39 ± 0.05
	2	3.20 ± 0.00	0.47 ± 0.01	0.30 ± 0.01	0.80 ± 0.01	2.40 ± 0.08
	4	3.19 ± 0.01	0.46 ± 0.00	0.29 ± 0.01	0.77 ± 0.02	2.42 ± 0.03
	mean	3.22	0.47	0.30	0.81	2.40
sorghum	0	1.85 ± 0.03	0.29 ± 0.01	0.15 ± 0.00	0.50 ± 0.02	1.34 ± 0.05
	1	1.85 ± 0.01	0.29 ± 0.01	0.15 ± 0.00	0.50 ± 0.01	1.33 ± 0.04
	2	1.83 ± 0.01	0.28 ± 0.00	0.14 ± 0.00	0.48 ± 0.02	1.35 ± 0.03
	4	1.80 ± 0.00	0.27 ± 0.00	0.14 ± 0.00	0.44 ± 0.01	1.36 ± 0.06
	mean	1.83	0.28	0.15	0.48	1.35
cereals	SEM	0.30	0.07	0.02	0.03	0.04
	CD ($P < 0.05$)	0.90	0.21	0.06	0.09	0.12
storage period	SEM	0.40	0.06	0.03	0.04	0.05
	CD ($P < 0.05$)	NS	NS	NS	NS	NS
cereals × storage period	SEM	0.60	0.08	0.06	0.07	0.07
	CD ($P < 0.05$)	NS	NS	NS	NS	NS

[a] Values are means ± SD of six independent determinations. SD denotes standard deviation. SEM denotes the standard error of the mean across all treatments. CD denotes critical difference. Differences of two means between the cereals/storage period exceeding this level are significant.

in lipids and their classes as a result of insect infestation (Table 2). Losses at different infestation levels due to *T. granarium* varied from 4 to 21% (total lipids), 6 to 33% (phospholipids), 7 to 42% (galactolipids), 6 to 30% (polar lipids), and 5 to 18% (nonpolar lipids), and these were comparatively lower in the case of *R. dominica*. Similarly, in sorghum grains (Table 3) *T. granarium* also caused 3−22, 17−41, 27−53, 16−40, and 2−17% losses in total lipids, phospholipids, galactolipids, polar lipids, and nonpolar lipids, respectively. Corresponding losses due to *R. dominica* infestation were 2−10, 10−31, 13−40, 8−22, and 1−9%. Galactolipids suffered more losses as compared to other classes of lipids in sorghum and maize grains due to infestation of both insect species. The mixture of both insect species caused intermediate losses. Depletion of lipids in cereals as a result of insect infestation is also evident from correlation studies (Table 4). Total lipids and lipid classes of three cereal grains except nonpolar lipids of sorghum and total lipids of maize were found to be negatively and significantly ($P < 0.05$) correlated with the infestation of *T. granarium*. The infestation of *R. dominica* manifested significant and negative correlations with phospholipid content of wheat, galactolipids, phospholipids, and polar lipids of sorghum, and all lipid classes of maize except nonpolar lipids.

Effect of Storage. During storage (1−4 months), variations in total lipids, phospholipids, galactolipids, polar lipids, and nonpolar lipids of three cereal grains were very small and nonsignificant (Table 5).

DISCUSSION

Changes in the quantity of various lipids of three cereal grains stored for 1−4 months in insect free conditions were nonsignificant. However, in other studies, storage of wheat flour (Premavalli *et al*., 1973; Warwick *et al*., 1979), pearl millet flour (Patel and Parameswaran, 1992), and brown rice (Indudharaswamy *et al*., 1993) for 1−13 months resulted in significant degradation of lipids which may be attributed to processing of grains into flour and different storage conditions.

Among insects, *T. granarium* caused more losses of lipids as compared to *R. dominica*, and the observed differences may be due to the distribution of lipids in seed components. In wheat seed components, lipid distribution has been reported as 3.8% in endosperm, 10% in germ, and 8% in bran (Aykroyd and Doughty, 1970). Similarly in maize also, fat was more concentrated in germ (18.5%) as compared to bran (0.98%) and endosperm (0.86%) as reported by Earle *et al*. (1946). Interestingly, germ of sorghum grains contains the maximum (76.2%) level of oil followed by endosperm (13.2%) and bran (10.6%) (Hubbard *et al*., 1950). For this reason, lipids were more exposed to primarily germ feeder *T. granarium* than endosperm feeder *R. dominica*. Comparatively higher level of infestations (50 and 75%) caused significantly more losses of lipids in three cereal grains. In earlier studies (Pandey and Pandey, 1977; Pant and Susheela, 1977; Nirmala and Kokilavani, 1980; Sudhakar and Pandey, 1981, 1987), insect infestation has been reported to decrease oil contents of maize, wheat, rice, and sorghum grains but levels of infestation, effects on various lipid classes, and the comparative roles of individual insect species were not considered. In the present studies, phospholipids in wheat and galactolipids in sorghum and maize were more adversely affected than other classes of lipids due to attack of both insect species. It may be inferred from the present investigations that losses of lipids in cereal grains as a result of insect infestation are related to the varying distribution of lipids in seed components of different cereals, the extent of insect infestation, and the type of insect species involved.

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