Grain Storage insect-pest infestation- Issues related to food quality and safety

Prachi Singh¹, Santosh Satya², S. N. Naik³

Center for Rural Development and Technology, Indian Institute of Technology Delhi, New Delhi 110016, India

Abstract

Wheat is a staple food in several countries and serves as a good source of carbohydrates, B vitamins and some minerals including the important trace elements like Selenium in vegetarian diets of majority of population. But unfortunately, due to poor post harvest storage and pets attack 10-30% of grains are wasted. insect pest infestation has been reported to deteriorate the quality of cereals in terms of proteins, amino acids, starch vitamins, etc. and is also responsible for creating unhygienic conditions due to mixing of insect fragments making it unfit for consumption. Food safety is an area of concern as it has a direct impact on human health. In this background, the review paper demonstrates the critical analysis done by various researchers on quality parameters of infested wheat along with a pragmatic solution to the serious problem related to food quality and safety.

Key words: wheat, insect infestation, R.dominica, T.granarium

Introduction

Wheat (Triticum) is an important dietary component of human food in several countries including India. It proves to be a good source of carbohydrates, B vitamins and some minerals including trace elements like selenium in vegetarian diets of majority of population of Asia and Africa. To a large extent much of the protein requirements are met by wheat grains. However, it is vulnerable to attack by several insect- pests like Rhizopertha dominica, Trogoderma granarium, Sitophilus oryzae etc. during storage.

Of these Rhizopertha dominica Fabricius (Coleoptera Bostrichidae), commonly called as lesser grain borer and Trogoderma granarium (Khapra beatle) are notorious pests of cereals mainly wheat, rice and sorghum. R.dominica is highly polyphagous and present throughout warmer regions of the world (Edde et al., 2005). At high levels of infestation, it devours the entire kernel and reduces the grain to thin skins. Grain loss in cereals due to pests varies from 10 to 30% (Ferry et al., 2004).

However, Rhizopertha dominica is not known to attack the standing crop but due to its potent flight ability, it can easily migrate from one granary to the other creating a menace. Although, T.granarium, an equally dreaded pest of wheat, is unable to fly but has spread all over the world with cargo (A Guide To The Beetles of Australia, 2010). Insect pest infestation has been reported to hamper the quality of cereals in terms of protein, amino acids, starch, vitamins etc. It is also responsible for creating unhygienic conditions due to mixing of insect fragments making it unfit for consumption.

This paper presents a comprehensive review and critical analysis of work done by various researchers on the above aspects along with a pragmatic solution to the serious problem related to food quality and safety.

Materials and Methods

Wheat- varieties, storage and food products, Since time immemorial, wheat (Triticum spp) has been regarded as staple food for major civilizations of Europe, West Asia and North Africa. It is the best of the cereal foods and provides more nourishment to humans than any other food source. It is considered as the supreme diet component due to its agronomic adaptability, ease of grain storage and simple processing methods for preparing variety of food products providing palatable satisfaction. Wheat is the most

* Corresponding author. E-mail prachi_singh11@yahoo.co.in
important source of carbohydrate in a majority of countries and it also supplements minerals, vitamins and fats (lipids). In India 90% of wheat is consumed in form of chapati and 10% as bread, biscuit and buns and other bakery products prepared from wheat flour. India is the second largest producer of wheat in the world and in 2003-04 produced 72 million tons of wheat which contributed to 12% of world production (Changing Face of Processed Food Industry in India, 2008) The desired quality of wheat flour is obtained by efficient separation of starch of endosperm from hard and indigestible outer husk of wheat from aleurone layer and germ. Separation is achieved by passing the grains between horizontal rollers known as ‘break rolls’ and passing the grit through sieves ‘plan sifter’. Break rolls convert grains into semolina (suji-small granules made up largely of endosperm). The outer husk is sifted out as bran or coarse wheat feed. Semolina is purified by passing through a series of sieves to remove any husk and then passed through a gradual reduction system consisting of smooth rollers called reduction rolls to get a fine flour of starch.

Whole meal flour is obtained by milling the whole wheat without separation of bran, germ, endosperm and scutellum. It is dark in colour and bread made from it is coarse (Food Processing and Preservation, 2005). It is also used to prepare typical Indian unleavened breads such as chapatti, parantha, roti, khakra. Of these, chapatti, khakra and roti are roasted after rolling, paranthas are shallow fat fried and puris are deep fat fried. Leavened products of wheat flour include nans (roasted after rolling), bhatura(fat fried) and bread(baked in oven ). Nans and bhatura are leavened by addition of curd to flour by making dough whereas bread is leavened by yeast (Food Science, 2006).

Globally wheat is grown on more than 240 million ha, larger than for any other crop, and its world trade is greater than for all other crops. International wheat production statistics reveal total wheat production was 651.4 million metric ton during 2010. (Briggle, 1980). All over the world 25 species of wheat are recognized which are divided into three major groups on the basis of chromosome number- hexaploid, tetraploid and diploid (Fadden et al., 1946; Lev-Yadun S et al. 2000). However, in India only three species- T.aestivum/vulgare (Bread wheat), T.durum (Macroni wheat) & T. dicoccum (Emmer wheat) are grown commercially. Grading of wheat is done on the basis of-

i) Protein content (9-14%),

ii) Kernel texture (hard, semi hard, soft)

iii) Colour(white amber,, red) (ncme.com).

Table 1. Landmark varieties of wheat in India and their yielding ability (dwr.in)

<table>
<thead>
<tr>
<th>Variety</th>
<th>Year of release</th>
<th>Yield potential (Q/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>S 227</td>
<td>1965</td>
<td>33.7</td>
</tr>
<tr>
<td>C 306</td>
<td>1965</td>
<td>36.0</td>
</tr>
<tr>
<td>Sonalika</td>
<td>1967</td>
<td>45.5</td>
</tr>
<tr>
<td>Kalyan Sona</td>
<td>1970</td>
<td>46.0</td>
</tr>
<tr>
<td>WL 711</td>
<td>1975</td>
<td>46.8</td>
</tr>
<tr>
<td>UP 262</td>
<td>1977</td>
<td>44.0</td>
</tr>
<tr>
<td>WH 147</td>
<td>1977</td>
<td>45.1</td>
</tr>
<tr>
<td>HD 2189</td>
<td>1979</td>
<td>45.7</td>
</tr>
<tr>
<td>HD 2009</td>
<td>1980</td>
<td>45.8</td>
</tr>
<tr>
<td>Lok 1</td>
<td>1981</td>
<td>45.4</td>
</tr>
<tr>
<td>HUW 234</td>
<td>1984</td>
<td>35.3</td>
</tr>
<tr>
<td>HD 2285</td>
<td>1985</td>
<td>42.5</td>
</tr>
<tr>
<td>HD 2329</td>
<td>1985</td>
<td>47.1</td>
</tr>
<tr>
<td>UP 2338</td>
<td>1990</td>
<td>51.3</td>
</tr>
<tr>
<td>WH 542</td>
<td>1992</td>
<td>61.5</td>
</tr>
<tr>
<td>Raj 3765</td>
<td>1995</td>
<td>48.9</td>
</tr>
<tr>
<td>PBW 343</td>
<td>1995</td>
<td>63.0</td>
</tr>
<tr>
<td>HD 2687</td>
<td>1999</td>
<td>62.9</td>
</tr>
<tr>
<td>HD 2733</td>
<td>2001</td>
<td>61.5</td>
</tr>
<tr>
<td>GW 322</td>
<td>2002</td>
<td>61.0</td>
</tr>
<tr>
<td>DBW 17</td>
<td>2006</td>
<td>64.1</td>
</tr>
</tbody>
</table>

Figure 1. Food products obtained from wheat
Life cycle of *Rhizopertha dominica* (*R.dominica*) and *Trogoderma granarium* (*T.granarium*) - *Rhizopertha dominica*, *Rhyzopertha dominica*, is a member of the family Bostrichidae known as auger beetles or, powderpost beetles. There are about 550 bostrichid species in 99 genera of which 77 species in 26 genera occur in North America (Marske and Ivie, 2003). Bostrichids are reddish-brown to dark-brown in color. They vary in sizes, are elongated, cylindrical in cross-section, and their head is invisible when viewed from above. The insects live mainly in dead and dried wood, and are pests of timber ([Potter, 1935], [Fisher, 1950], [Mathew, 1987], [Ivie, 2002a] and [Ivie, 2002b]). *Rhizopertha dominica* is the only species in the genus *Rhizopertha*.

**Life cycles - Egg**, The life cycle includes four stages: egg, larva, pupa, and adult. *Rhizopertha dominica* eggs are deposited in clusters on grains or singly among the frass produced by the insect. Freshly laid egg is opaque, whitish in color with a waxy appearance, but after a little while it becomes pinkish in color. The egg surface appears smooth, but scanning electron micrograph (SEM) magnification reveals a distinct granulated microstructure. (Kucerova and Stejskal, 2008)

**Larvae**, There are on an average four instars in *R. dominica* ([Potter, 1935], [Howe, 1950] and [Thompson, 1966]). The first instar is about 0.78 mm long and 0.13 mm wide across the head capsule (Potter, 1935). The larva is very active, and moves rapidly around the grains. The second instar is similar in shape to the first instar, but larger in size, being about 1.1 mm long, and 0.17 mm across the head capsule (Potter, 1935). The third and fourth stages are curved and scarabaeiform in shape, and are largely immobile. There is no noticeable difference in color among the first, second, and third instars. However, in the fourth instar, the ventral region is whitish, the head is light brown, and the color of the mandibles dark-brown or nearly black. The length of the mature fourth instar is approximately 3.2 mm and the head is approximately 0.41 mm in diameter. Development through all instars takes about 16 days under optimal conditions for rapid development of the larval stage, which are 34°C and 70% RH in wheat kernels of 14% moisture content ([Birch, 1945a] and [Birch, 1945b]).

**Pupa**, Young pupae are whitish in color, but later, eye and mouthparts turn brown. Average lengths of the body and head capsule are 3.9mm and 0.6 mm respectively.

The optimum conditions for rapid development of the pupal stage are 34 °C and 70% RH in wheat kernels of 14% moisture content ([Birch, 1945a], [Birch, 1945b], [Birch, 1945c] and [Birch, 1953]); which allows pupa to develop in 4 days. During the pupal stage, it is possible to distinguish between the sexes. Sexual dimorphism is displayed at the tip of the abdomen. The genitalia of the females are divergent, three-segmented, and protuberent whereas those of the males are convergent, two-segmented, and protuberant ([Potter, 1935] and [Halstead, 1963]).

**Adults**, The adult beetle is 2–3 mm long and 0.8–1 mm wide. The insect is reddish-brown to dark brown in color. Mean longevity of adult male and female *R. dominica* fed on wheat kernels at 28°C and 65% RH is 26 and 17 weeks respectively (Edde and Phillips, 2006b)

*Trogoderma granarium*, Trogoderma granarium Everts(Coleoptra : Dermestidae) commonly known as the Khapra beetle is a destructive pest of stored grains. It is phytophagous member of the family Dermestidae, in larval stage. It has also been regarded as master of survival and can endure starvation for years, hiding in small nooks and crannies.

**Life stages of Trogoderma granarium**, Life cycle is dictated by temperature: 35 days at 34°C and 120 days at 120°C. The average life span of adults is around 10-12 days.

**Eggs**, Eggs are cylindrical with one end pointed bearing pine like projections (which are broader at the base and taper distally) while the other end is rounded. They measure 0.7mm long and 0.25mm wide. They are transluscent white but yellowish or reddish marks develop on chorion. Eggs hatch in 3- 15 days depending upon the temperature. A female can lay 50-100 eggs t a time. They can live upto nine generations a year (A Guide To The Beetles of Australia, 2010).

![Figure 2. Life cycle of *Rhizopertha dominica* Pupa](image)

![Figure 3. Life cycle of *Trogoderma granarium* Larvae](image)
Yellowish brown or brown with numerous long hair on dorsal surface. Younger larvae bear a brush of long hair on 9th abdominal segment that projects like a tail which diminishes as they age. Generally larval period takes 15 days. Male larvae undergo four instars where as females undergo five instar. Mature larva is approximtely 6mm in length and 1.5 mm in breadth.

- Pupa, Pupation gets complete within 3-5 days. Pupa is 5mm long in colour and bears a medial ridge of long hair dorsally.

- Adults. They are small 1.8-3.8mm long with yellowish brown to reddish brown in colour with pronotum usually darker than elytra bearing indistinct reddish brown marks. They are oblong – oval in shape and females are larger than males, lighter in color, antenna are 11 segmented, head is small and usually deflexed (Urban Pest Management in Australia, 2008; Elements of Entomology, 2007).

Effect on Quality parameters, Literature survey reveals that studies on this important aspect are very limited. These have been carried out by creating artificial infestation at different levels by selected insect- pests of stored grains.

Protein digestibility, Digestibility may be regarded as an indicator of availability of protein for bodily growth and stamina. It measures the susceptibility of protein to proteolysis. Thus, a protein with high digestibility is of better nutritional quality than one of low digestibility as it would yield more amino acids for absorption upon proteolysis (Duodu et al., 2003).

A study was conducted to calculate in-vitro digestibility of protein by the method of Akeson & Stahman (1964) subsequently modified by Singh & Jambunathan (1981). It showed that Protein Digestibility of uninfested grains was 72.9% which decreased to 68.0%, 61.3 % & 50.5% (R.dominica); 65.2%, 56.6%,45.5% (T.granarium) and 67.4%, 58.2% and 47.3% (T.granarium + R.dominica i.e. mixed infestation) at 25,50 and 75% infestation levels respectively (Jood et al., 1991). It is evident from the values that T.granarium caused much sharper decline (11-38%) in protein digestibility as compared to R.dominica (7-31%) and mixed population (8-35%) because it is a germ feeder and germ possesses higher concentration of proteins than endosperm.

Starch Digestibility, Starch is the major carbohydrate reserve (Osagie et al., 1992) found as granules typically consisting of 10-30% amylase and 70-90% amylopectin (Alais et al., 1999). It is organized in concentric alternating semi crystalline and amorphous layers in granules of various sizes within endosperm (Svihus et al., 2005).

Size of starch granules affects digestibility. As size of granule increases, contact between substrate and enzyme decreases. Wheat has large starch granules which signifies low starch digestibility as compared to cereals with small starch granules like rice and oats (Manelius and Bertoft, 1996; Bednar et al., 2001). The digestibility is further exacerbated due to infestation. In – vitro starch digestibility was carried out by employing Pancreatic Amylase method (Singh et al., 1982). Reduction of 39% in starch content was recorded at 75% level of infestation caused by T. granarium whereas at the same level of infestation by R.dominica, a much higher reduction of 68% was observed (Jood et al., 1991). This can be explained on the pretext that starch (94.7% in endosperm of wheat) is an easy target for R.dominica. Hence, the endosperm feeder causes greater impact on starch digestibility as compared to T.granarium.

Lipid Content, Lipids are regarded as source of stored energy in adipose tissues and precursors for biosynthesis of many hormones. They constitute the frame work for cell membranes (Passmore and Eastwood 1986). For estimation, lipids were extracted by the method of Huber and Newman (1975) and total lipids in sample were determined gravimetrically. The quantity of phospholipids in the sample were determined by measuring lipid phosphorous (Broek huyse 1968), galactolipids on the basis of galactose content of lipids while non polar and polar lipids were determined by the method of Nichols (1964).

It was investigated that at different levels of infestation, T. granarium thinned down the level of total lipids (7-23%), galactolipids (12-32%), polar lipids (12-34%) and non polar lipids (5-18%). On the other hand, effect of R. dominica was less intense. Infested samples showed 0-11% reduction in total lipids, 0-17% in phospholipids, 0-15% in galactolipids, 0-12% in polar lipids and 0-9% in nonpolar lipids. The mixed population of both insects produced intermediate losses (Jood et al., 1996).Hence, it can be stated that phospholipids were the most affected lipid class due to infestation. T.granarium has a more pronounced effect on reduction of lipids as compared to R.dominica due to distribution of lipids in seed component. Lipid distribution in wheat has been reported as 3.8% in endosperm, 10% in germ and 8% in bran (Aykrod and Doughty, 1970). Thus, lipids were susceptible to primal attack by germ feeder (T.granarium) than endosperm feeder (R.dominica).

4.4 Micronutrient content

Mineral substances in the wheat grains are represented by Phosphorous, Magnesium, Copper, Zinc, Manganese etc. Inadequate intake of these nutrients can alter immunocompetence in humans leading to increased susceptibility to illness (Sheraman 1992 ;O. Del, 1976 and Kaushik et al., 2010).

Analysis concerning the content of microelements on wheat infested by Rhizopertha dominica at different levels was conducted. It was monitored that microelements viz. Cu (5-19%), Zn (2-3%) and Mn (4-5%) undergo reduction. A probable reason for this trend is metabolism of elements by insect population (Lavinia et al., 2011). Amount of copper exhibits the maximum downfall. Copper, component of numerous cuproenzymes, plays an imperative role in many physiological functions such as development and maintenance of cardiovascular and skeletal integrity, central
nervous system structure and function and erythropoietic function including iron metabolism (Sheraman 1992 and O. Del, 1976).

**Macronutrients**, Micu and Petanec (2009a) analyzed the content of macro-elements (Ca, Mg, K, Na, Fe) in cereals grains infested and attacked by Rhizopertha dominica after 30 days. According to research findings ash content and macro-elements content (Na, K, Ca, and Fe, except Mg) of the analyzed wheat grains, an increasing trend as compared to the sample control (non-infested) was noted. This increase can be explained by the fact that the insects eliminated macrolelements through excrements and exuviae as well as part of the amount of macroelements existing in their bodies during the infestations.

**Protein content**, Proteins are nitrogen containing substances that are formed by amino acids and serve as major structural component of muscle and other tissues in the body. They are also used for biosynthesis of hormones, enzymes and hemoglobin (Hoffman and Michael, 2004). A study was conducted to monitor true protein, total nitrogen, non protein nitrogen and protein nitrogen in wheat grains infested by Rhizopertha dominica and Trogoderma granarium at different infestation levels. True protein and total nitrogen was estimated by the method of Osborne and Voogt (1978) and by Micro Kjeldahl method (AOAC, 1980) respectively:

Non protein nitrogen = Total protein nitrogen - True protein nitrogen

Total protein = 5.7 × (Nitrogen content)

(Pingale et al., 1954; Sudhakar & Pandey 1987; Hira et al., 1988) and Jood & Kapoor (1992) Rise in total nitrogen and total protein is attributed to increase in non protein nitrogen due to insect-pest infestation. T.granarium feeding has decreased true protein content more tremendously from 11.8% (uninfested grains) to 9.0 -11.0% in 75% infested grains as compared to Rhizopertha dominica because wheat grains contain higher proportions of true protein in the germ (26%) and bran (48%) components of seed (Aykroyd & Doughty, 1970) which are readily damaged by the germ feeder (Girish et al., 1975).

**Amino acid content**, Amino acids are organic compounds that combine to form proteins. Together with proteins, they are the building blocks of life. They are required for several vital functions in human body such as break down of food, growth, repair of body tissues etc. Amino acids are classified into three groups:

- **Essential amino acids**: These cannot be synthesized by the body. As a result, they must be supplemented from food. The nine essential amino acids are: histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, and valine.

- **Nonessential amino acids**: These can be synthesized by the body. They include: alanine, asparagine, aspartic acid, and glutamic acid.

- **Conditional amino acids**: They are usually not essential, except in times of illness and stress. They include: arginine, cysteine, glutamine, tyrosine, glycine, ornithine, proline, and serine (Trumbo et al., 2002; Escott- Stump et al., 2008).

Under the glare of scrutiny, Jood et al., (1995) reported decadence in essential amino acids of wheat due to infestation cause by mixed population of Rhizopertha dominica and Trogoderma granarium. Infestation markedly reduced methionine (38.9%) followed by leucine (20.3%), lysine (18.6%) and isoleucine (14.2%).

Recently, it has been reported that methionine being one of the twenty essential amino acids is vital for growth and cellular metabolism of insects as well as for humans (Shen Luo and Rodney L. Levine, 2008). The diminution of amino acids eventually reflects stupendous downfall in calorific value depleting the nutritive quality of grains. However, Micu et al., (2009) observed that the most consumed essential amino-acid by Rhizoperta dominica alone, is valine followed by isoleucine and histidine.

**Carbohydrate content**, Carbohydrates are one of the main dietary components which include sugars, starches, and fiber. Their primary function is to provide energy for the body, especially the brain and the nervous system. Carbohydrates are broken down into glucose (blood sugar) by amylase enzyme, which is used for energy by the body (Dietary Guidelines for Americans, 2010).

Jood et al., 1991; studied the effect of Rhizopertha dominica and Trogoderma granarium at 25, 50 and 75% infestation level on carbohydrate content of infested wheat grains. Total sugars were extracted (Cerning et al., 1973) and estimated (Yem et al., 1954). Reducing sugars were estimated by Somogyi’s modified method (1945).

Amount of non reducing sugar = Total soluble sugar – Reducing sugar

Starch from sugar free pellet was estimated by the method of Clegg (1956).

It was inferred from the study that there was 8-60% reduction in total soluble sugar, 6-40% in reducing sugar, 9-60% in non reducing sugar and 12-64% in starch at different levels of infestation by R.domicina whereas infestation of T.granarium showed 2 to 21% losses of total sugars, 1 to 8% of reducing sugars, 3 to 23% of non-reducing sugars and 8 to 39% of starch. Depletion in carbohydrates upon infestation by R.domicina is greater than by T.granarium as they are confined to endosperm of the seed i.e. exclusively attacked by R.domicina.

**Vitamin content**, There are a variety of B vitamins in wheat, such as thiamine, riboflavin, pyridoxine, niacin, pantothenic acid, biotin and folicates. These molecules are water-soluble and play an important role in metabolism, particularly the metabolism of carbohydrates (thiamine), proteins and fats (riboflavin and pyridoxine) (Batifoulier et al., 2006).

A study conducted by Jood et al., (1994) reveals substantial loss in vitamins (riboflavin, thiamine & niacin) of wheat at
three infestation levels (25, 50 and 75%) caused by releasing Rhizopertha dominica, Trogoderma granarium and mixed population of both.

Thiamine, riboflavin and niacin were determined by thiochrom, fluorimetric and colorimetric method respectively (AOAC Method, 1980). Losses were to the extent of 23 to 29% (thiamine), 13 to 18% (riboflavin) and 4 to 14% (niacin) at 50% and 75% infestation caused by R.dominica. Thus, niacin undergoes maximum depletion due to R.dominica infestation. On the contrary, infestation at 50% and 75% level by T. granarium resulted in losses 31-69% (thiamine), 25-50% (riboflavin) and 5-10% (niacin). Hence, T. granarium caused higher loses of thiamine and riboflavin as compared to R. dominica whereas mixed population gave intermediate results. The varied loss in different vitamin content can be regarded to nature of damage caused by pest as well as distribution of vitamins in seed component (Jood et al., 1993). Vitamins have been reported to be mainly concentrated in aleurone layer and bran/germ portion of seed (Salunkhe et al., 1995; Daniel et al., 1977; Hubbard et al., 1950). Hence, Rhizopertha dominica being endosperm feeder causes comparatively less damage to vitamin content of grains.

Vitamin E is a fat soluble vitamin that occurs in nature in several forms, namely tocopherols and tocotrienols. Wheat is a good source of tocopherols which are known to delay the pathogenesis of a variety of degenerative diseases, such as cardiovascular disease, cancer, inflammatory diseases, and in the maintenance of the immune system (Bramley et al., 2000). Recently, it has been found that the content of tocopherol plunged by 0.15%, 0.41% and 0.51% at 25%, 50% and 75% level of infestation by R.dominica respectively (Micu et al., 2009b).

**Uric acid content and organoleptic characteristics**, Uric acid is regarded as an index of insect population density and is related to kernel damage. Increased uric acid level is not only alarming from hygienic and nutritional point of view but also elevates the risk of causing gout. High levels of uric acid can even cause uric lithiasis and acute chronic nephropathy, due to the deposit of urate crystals (B. Álvarez-Lario and J. MacArrón-Vicente, 2011). At 50% level of infestation caused by Rhizopertha dominica, uric acid content was calculated to be 19.0 ± 0.18 mg/100g where as by Trogoderma granarium was found to be 15.5 ± 1.10mg/100g as per AOAC method described by Oser 1971. Uric acid value as obtained by Rhizopertha dominica infestation is above acceptable limits (100mg/kg) signifying greater contribution to uric acid level by Rhizopertha dominica.

It is an important parameter for assessing the organoleptic characteristics also. Although, even high infestation levels do not affect colour, appearance, aroma and texture but leads to an abhorrent and bitter taste. Duration of storage period and extent of infestation levels marks the uric acid level. Longer be the storage period, higher be the risk of infestation and hence higher be the level of uric acid.

**Antinutrient contents – Polyphenols and Phytic acid**, It was monitored that till four months of storage, polyphenol content did not change much but there was a marginal increase in phytic acid content. On the other hand, if the same stored grains were analyzed for vitamins and starch, they display a significant reduction (Jood et al., 1990; Jood et al., 1993).

When polyphenol and phytic acid content were estimated in wheat grains infested by Rhizoperta dominica according to Folin Denis procedure (Swain and Hills, 1959) and Hang Lantzch (1983) respectively, both exhibited appreciable increase. Polyphenols constitute one of the most numerous and ubiquitous groups of plant metabolites. They bind and precipitate macromolecules, such as dietary protein, carbohydrate, and digestive enzymes, thereby reducing food digestibility (Laura Bravo, 1998).

Rhizoperta dominica feeds exclusively on endosperm of wheat sparing the testa layer which is reported to contain polyphenols. Hence selective feeding leads to proportional increase (8-22%) in polyphenol content, while T.granarium caused 8% increase in polyphenol content of wheat. The slower rate of accumulation of polyphenol in wheat infested by T.granarium is due to its feeding habit. The germ feeder causes slight damage to the bran (consisting of pericarp and testa layer) portion of seed (Atwal, 1976). The mixed feeding of both insect species produced intermediate results. Wheat contains 70% of phosphorous in the form of phytic acid (Inositol hexaphosphate) which is concentrated in bran layer (41.2%) and germ portion (3.91%) of seed where as endosperm contains only 0.004% of phytic acid (Reddy et al., 1982). The distribution pattern signifies that phytic acid is exposed to attack by T.granarium and hence, there is marginal increase in content of phytic acid. Since Rhizoperta dominica nibbles off the endosperm, it leads to significant increase in phytic acid from 11% to 26% at high infestation level (Jood et al., 1995). The antinutritive effect of phytic acid is based on its molecule structure. At complete dissociation, phytic acid's six phosphate groups carry twelve negative charges which, in weak acidic to neutral pH conditions, bind different di- and trivalent cations (e.g.Ca, Mg, Fe, Zn, Cu, Mn) into a stable complex, thus hindering the bioavailability of vital nutrients. Under acid conditions, a negative influence of the phytic acid on the solubility of proteins can be expected because of the ionic binding between the basic phosphate groups of phytic acid and protonised amino acid (lysyl, histidyl and arginyl residue) (De Rham and Jost, 1979; Fretzdorff et al, 1995).

**Conclusions**

Analysis concerning the effect of insect-pest infestation on quality parameters of wheat are an important factor in assessing the nutritive value of grains. Pest attack affects protein and starch digestibility adversely which hinders the bioavailability of proteins to humans. Methione one of the
most vital amino acids for the growth and development of humans is reduced by 38% due to infestation by mixed population of T.granarium and R.dominica. Even the content of important vitamins (thiamine, riboflavin and niacin) of wheat is markedly reduced. Increase in antinutrients (polyphenol and phytic acid) further hampers the availability of nutrients. Staggering increase in uric acid level (above the safety limits) is undesirable and may aggravate the risk of diseases like gout.

On the whole, insect-pest infestation not only reduces the quantity of grains but impairs the quality as well. Therefore, need of the hour is to adopt appropriate methodologies to salvage the stored grains from pest attack. A recent investigation by Kaushik et al., 2010 showed that pesticide residue in chick peas hinders the bioavailability of micronutrients. This serious issue is an area of concern and demands extensive research to alleviate the potential problem of grain loss.

In India wheat grains are stored in traditional house hold grain storage system as well as large scale centralized system managed by two main government agencies- Food Corporation of India and Central Ware Housing Corporation. As the basic nature of food is to remain diverse, decentralized small scale storage system are generally managed and monitored properly leading to better food quality and safety. Above research findings reveal great concern for industrial food products based on wheat grains where stored grain pest infestation cannot be determined, thus making the quality control process extremely difficult. Hence, in the light of above limited but significant research findings in depth analysis of grains infested in a natural way under field conditions especially in centralized system needs to be carried out. Obviously eco friendly botanical formulations for controlling single and multiple pest infestation in stored wheat especially for centralized grain storage system need to be developed and made commercially available.

References


AOAC Official Methods of Analysis, 13th edn.


Atwal AS, 1976.Agricultural Pests of India and South-East Asia; Kalyani Publishers: Ludhiana,


Edde P A, Phillips TW, and Toews MD, 2005 Responses of Rhyzopertha dominica (Coleoptera: Bostrichidae) to its aggregation pheromones as influenced by trap design, trap height and habitat. Environ Entomol 34: 1549–1557.


Curculionoidea, vol. 2. CRC Press, Boca Raton, pp. 233-244.


