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Effect of storage and insect infestation on protein and starch digestibility of cereal grains

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Protein and starch digestibility of wheat, maize and sorghum grains increased marginally during storage, except for starch digestibility of sorghum which increased significantly ($P<0.05$) after 4 months of storage. Protein and starch digestibility of three cereal grains having 25, 50 and 75% grain infestation caused by *Trogoderma granarium* Everts and *Rhizopertha dominica* Fabricius separately and in mixed form were affected significantly ($P<0.05$) and adversely. *T. granarium*, primarily a germ feeder, reduced protein digestibility of wheat and maize more than did *R. dominica* or a mixed population of both insect species. By contrast, *R. dominica*, an endosperm feeder, reduced starch digestibility of three cereal grains compared with *T. granarium* and a mixed population. The reduction in digestibility was dependent on the distribution of proteins and starch in seed components as well as feeding preferences of insects.

INTRODUCTION

Wheat, maize and sorghum grains are important sources of carbohydrates, proteins, certain minerals and B-vitamins in the vegetarian diets consumed by a majority of the population of Asia and Africa. During varied storage conditions, these cereal grains are attacked by several insect pests and weight losses are accrued to the extent of 23% in India (Swaminathan, 1977). Among insect pests the khapra beetle (*Trogoderma granarium* Everts) and the lesser grain borer (*Rhizopertha dominica* Fabricius) cause major storage losses in cereals in India (Girish *et al.*, 1975) and several other tropical and sub-tropical regions of the world (Salunkhe *et al.*, 1985). Although infestation of these pests has been reported to decrease carbohydrates and proteins in various stored food grains (Girish *et al.*, 1975; Swaminathan, 1977; Jood, 1990), information is still lacking on the effect of graded infestations and storage periods on protein and starch digestibilities in wheat, maize and sorghum, which led to the present investigations.

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MATERIALS AND METHODS

Mass culture of two insect species, *Trogoderma granarium* Everts and *Rhizopertha dominica* Fabricius, was carried out in the laboratory at an ambient temperature of 28–30°C and a relative humidity of 60–90%. The grains of commonly consumed varieties of wheat, maize and sorghum, apparently free from insect infestation, were further subjected to aluminium phosphide fumigation to eliminate any invisible insect populations. After fumigation, the grains were put in glass jars (20 cm × 15 cm), each jar containing 1·5 kg of grains. The jars, covered with muslin cloth kept in place with elastic bands, were placed in the laboratory for 10 days to facilitate conditioning of the grains. On the 10th day, the moisture level of the grains ranged from 10 to 11%, which is congenial for multiplication of both insects (Pingale & Girish, 1967). The jars of each food grain were subdivided into three sets.

In the first set of each food grain, 60 larvae (damaging stage of the pest) of *T. granarium* per jar were released to obtain three levels of infestation (25, 50 and 75% in three replicates). In the second set, 60 adults (more harmful than the larval stage) of *R. dominica* were released. In the third set, mixed populations of both species (30 larvae of *T. granarium* + 30 adults of *R. dominica*) were released to achieve three infestation levels. In each set, controls (jars without insects) were also kept to study the effect of stor-

Table 1. Effect of storage on *in vitro* protein and starch digestibility of wheat, maize and sorghum grains (per cent dry matter basis)[a]

Storage period (months)	Protein digestibility			Starch digestibility		
	Wheat	Maize	Sorghum	Wheat	Maize	Sorghum
0	72·9±2·12	71·0±2·90	64·5±2·52	31·6±1·20	40·3±1·00	37·0±1·0
1	73·7±2·80(1)	71·7±3·22(2)	65·1±3·00(1)	31·9±1·00(1)	41·0±0·59(2)	37·4±1·00(1)
2	76·6±3·00(4)	73·8±1·92(4)	66·5±2·09(3)	32·5±0·98(2)	42·0±1·28(4)	39·1±0·59(6)
4	78·8±2·09(8)	75·6±1·56(7)	69·2±1·98(7)	35·0±0·85(9)	44·1±1·30(10)	41·6±1·02(12)
SE(m)	3·25	2·70	2·75	1·75	1·75	1·75
CD(P<0·05)	NS	NS	NS	NS	NS	5·20

[a] Values are means ± SD of six independent determinations. Figures in parentheses are per cent increase over control.

age periods. It took 1, 2 and 4 months to obtain 25, 50 and 75% levels of infestation, respectively, at ambient laboratory temperature (28–39°C) and relative humidity (50-90%). When the desired levels of infestation approached, grains were immediately disinfected with aluminium phosphide fumigation to prevent further damage. Grains were cleaned and powered in a cyclotec mill to pass through a 60 mesh sieve and then stored in air-tight polyethylene bottles for chemical analysis.

Protein digestibility

In vitro digestibility of protein was carried out by the method of Akeson and Stahman (1964) as modified by Singh and Jambunathan (1981).

Starch digestibility

In vitro starch digestibility was carried out by employing pancreatic amylase (Singh *et al.*, 1982).

Statistical analysis

The data were subjected to analysis of variance (ANOVA) in a completely randomized design to find differences among treatments (Snedecor & Cochran, 1968).

RESULTS AND DISCUSSION

Effect of storage on protein and starch digestibility

Variations in protein digestibility in wheat (72·9–78·8%), maize (71·0–75·6%) and sorghum (64·5–69·2%) were observed at 0, 1, 2 and 4 months of storage (Table 1). The lower values of protein digestibility of sorghum compared with other cereals may be due to the higher amounts of tannins, polyphenols and phytic acid in sorghum (Salunkhe *et al.*, 1985; Jood, 1990)

Table 2. Effect of insect infestation on *in vitro* protein digestibility of wheat, maize and sorghum grains (per cent, on dry matter basis)[a]

Insect species	Infestation level (%)	Protein digestibility		
		Wheat	Maize	Sorghum
T. granarium	25	65·2±1·52(11)	59·1±2·24(17)	58·3±1·66(10)
	50	56·6±1·78(22)	53·0±1·61(25)	51·0±1·59(21)
	75	45·5±2·00(38)	41·4±1·90(42)	43·3±1·00(33)
	Mean	55·8	51·2	50·9
R. dominica	25	68·0±2·01(7)	64·0±2·01(10)	55·6±1·52(14)
	50	61·3±2·42(16)	60·2±2·82(15)	48·0±2·83(26)
	75	50·5±1·50(31)	50·4±2·93(29)	37·0±2·93(43)
	Mean	59·9	58·2	46·9
T. granarium + *R. dominica*	25	67·4±1·80(8)	62·3±1·85(12)	61·2±1·77(5)
	50	58·2±1·90(20)	58·2±1·26(18)	57·8±3·00(10)
	75	47·3±2·00(35)	48·1±1·00(32)	42·1±2·22(35)
	Mean	57·7	56·2	53·7
Control	0	72·9±2·11	71·0±2·91	64·5±2·55
Insect species	SE(m)	2·42	2·32	2·85
	CD(P<0·05)	NS	6·92	8·52
Infestation level	SE(m)	2·50	2·30	2·70
	CD(P<0·05)	7·50	6·90	8·12
Insect species x	SE(m)	4·62	4·20	5·20
Infestation level	CD(P<0·05)	13·8	12·6	15·6

[a] Values are means ± SD of six independent determinations· Figures in parentheses are per cent decrease over control.

which hinder the protein digestibility. There was a marginal increase (1–8%) in protein digestibility during storage. This increase may be due to hydrolysis of some protein into amino acid during storage.

Wheat had the lowest, maize highest and sorghum intermediate starch digestibility in fresh as well as in stored grains. Starch digestibility increased slightly in all three cereals during storage but differences were non-significant, except in sorghum where values of starch digestibility were significantly higher after 2 and 4 months of storage with fresh grains. The increase in starch digestibility during storage may be due to hydrolysis of starch into simpler products that are easily digested.

Effect of insect infestation on protein and starch digestibility

There was a proportionate and significant ($P<0.05$) decrease in protein digestibility with the increase in infestation levels (Table 2). In wheat, protein digestibility of uninfested grains was 72·9% which decreased significantly to 65·2%, 56·6%, 45·5% (*T. granarium*), 68·0%, 61·3%, 50·5% (*R. dominica*) and 67·4%, 58·2% and 47·3% (*T. granarium* + *R. dominica*) at 25, 50 and 75% infestation levels, respectively. *T. granarium* caused more reduction (11–38%) in protein digestibility compared with *R. dominica* (7–31%) and mixed population (8–35%). Similarly, in maize and sorghum there was a progressive and significant decrease in protein digestibility with the increase in levels of infestation. In maize, also, *T. granarium* resulted in higher reduction (17–42%) compared with *R. dominica* (10–29%) and mixed population of both species (12–32%). However, in sorghum, *R. dominica* affected protein digestibility more adversely (37.0–55.6%) compared with *T. granarium* (43·3–58·3%), mixed population of both insects (42·1–61·2%) and control (64·5%). The variations in reduction in protein digestibility were dependent on the type of insect species and food grain.

T. granarium is primarily a germ feeder (Pingale *et al.*, 1954), whereas *R. dominica* is an internal feeder and may cause more losses in endosperm contents (Swaminathan, 1977). Distribution of protein in bran, endosperm and germ of wheat was reported as 48·0, 23·9 and 26·0%, respectively (Aykroyd and Doughty, 1970). Likewise, in maize it was 13·2% in bran, 8·6% in endosperm and 34·4% in germ of the grain (Earle *et al.*, 1946). In sorghum grain, 80·9, 14·9 and 4·0% of total protein was recorded from endosperm, germ and bran, respectively (Hubbard *et al.*, 1950). Both insect species depleted the protein content on the basis of their feeding habits (Jood, 1990). Therefore, *T. granarium* caused more reduction in protein digestibility of wheat and maize grains because of the higher concentration of protein in germ than in endosperm. By contrast, *R. dominica* caused a higher reduction because of a higher content of protein in endosperm of sorghum grains. Reduction in protein digestibility in wheat grains stored for 11 months under natural conditions was previously observed by Hira *et al.* (1988) but the authors did not record the type of insect species involved.

Insect infestation also affected starch digestibility of three cereal grains (Table 3). There was a proportion-

Table 3. Effect of insect infestation on *in vitro* starch digestibility (mg maltose released g flour^{-1}) of wheat, maize and sorghum grains (per cent on dry matter basis)[a]

Insect species	Infestation level (%)	Protein digestibility		
		Wheat	Maize	Sorghum
T. granarium	25	27·6±0·58(13)	38·3±1·15(5)	33·5±1·50(9)
	50	24·6±0·92(32)	33·0±1·05(18)	28·0±0·86(24)
	75	19·3±1·10(39)	26·8±0·90(34)	24·0±1·00(35)
	Mean	23·8	32·7	28·5
R. dominica	25	24·6±0·61(22)	34·0±1·12(16)	30·1±1·10(19)
	50	18·9±0·00(40)	27·7±0·65(31)	24·5±0·88(34)
	75	10·2±0·08(68)	19·1±0·11(53)	12·5±0·09(66)
	Mean	17·9	26·9	22·3
T. granarium + *R. dominica*	25	26·6±1·16(16)	36·0±1·15(11)	31·2±1·15(16)
	50	20·0±0·69(37)	29·1±0·66(28)	26·0±1·50(30)
	75	13·5±0·55(58)	23·0±0·91(43)	12·6±0·16(66)
	Mean	20·2	29·4	23·4
Control	0	31·6±1·16	40·3±1·10	37·0±1·90
Insect species	SE(m)	0·74	0·75	0·74
	CD($P<0.05$)	2·22	2·25	2·22
Infestation level	SE(m)	0·75	0·75	0·74
	CD($P<0.05$)	2·25	2·25	2·22
Insect species *x* Infestation level	SE(m)	1·10	1·11	1·10
	CD($P<0.05$)	3·25	3·26	3·25

[a] Values are ± SD of six independent determinations. Figures in parentheses are per cent decrease over control.

ate and significant decrease in starch digestibility with the increase in infestation of grains caused by the two insects separately and a mixed population. Reduction was to the extent of 39% (wheat), 34% (maize) and 35% (sorghum) at 75% infestation level caused by *T. granarium*. At this level, *R. dominica* caused a significantly ($P<0.05$) greater reduction in starch digestibility of wheat (68%), maize (53%) and sorghum (66%) grains than that did *T. granarium*. Starch is an easier target for *R. dominica* due to the feeding behaviour of this pest. In sorghum 64·7% (Hubbard *et al.*, 1950), wheat 94·0% (Aykroyd and Doughty, 1970) and maize 86·6% (Earle *et al.*, 1946) of the starch is confined to the endosperm. Hence, the endosperm feeder *R. dominica* cause a significantly ($P<0.05$) greater reduction in starch digestibility compared with *T. granarium*. Mixed populations of both insect species cause intermediate reductions in digestibility. This may be due to the consumption of the digestible portion of starch by insects, the remaining portion of starch having less digestibility.

It may be inferred from the present investigation that protein and starch digestibilities of three cereal grains during storage are slightly affected but insect infestation at different levels caused significant reductions and the adverse effects were related to feeding habits of the insects and distribution of starch and protein in the anatomical components of the seeds.

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REFERENCES

Akeson, W. E. & Stahman, M. A. (1964). A pepsin – pancreatin digest index of protein quality evaluation. *J. nutr.*, **83**, 257–9.

Aykroyd, W. R. & Doughty, J. (1970). *Wheat in Human Nutrition*. FAO Nutritional Studies No. 23, Food and Agricultural Organisation of the United Nations, Rome.

Earle, F. R., Curtis, J. J. & Hubbard, J. E. (1946). Composition of the component parts of the corn kernel. *Cereal Chem.*, **23**, 504–11.

Girish, G. K., Kumar, A. & Jain, S. K. (1975). Part VI: Assessment of the quality loss in wheat damaged by *Trogoderma granarium* Everts during storage. *Bull. Grain Technol.*, **13**, 26–32.

Hira, C. K., Sadana, B. K., Mann, S. K., Kochar, A., Kanwar, J. & Sidhu, H. (1988). Changes in chemical constituents of wheat stored in different storage structures. *Bull. Grain Technol.*, **26**, 109–16.

Hubbard, J. E., Hall, H. H. & Earle, F. R. (1950). Composition of the component parts of the sorghum kernel. *Cereal Chem.*, **27**, 415–20.

Jood, S. (1990). Studies on nutritional quality of wheat, maize and sorghum as affected by infestation of *Trogoderma granarium* and *Rhizopertha dominica*. Ph.D. thesis submitted to Haryana Agricultural University, Hisar, India.

Pingale, S. V. & Girish, G. K. (1967). Effect of humidity on the development of storage insect pests. *Bull. Grain Technol.*, **5**, 101–8.

Pingale, S. V., Narayan, Rao, M. & Swaminathan, M. (1954). Effect of insect infestation on stored grain. 1: Studies on soft wheat. *J. Sci. Food Agric.*, **5**, 51–4.

Salunkhe, D. K., Chavan, J. K. & Kadam, S. S. (1985). *Post-harvest Biotechnology of Cereals*. CRC Press, Boca Raton, Florida.

Singh, U. and Jambunathan, R. (1981). Studies on Desi and Kabuli chickpea cultivars: the levels of protease inhibitors, levels of polyphenolic compounds and *in vitro* digestibility. *J. Food Sci.*, **46**, 1364–7.

Singh, U., Kherdekar, M. S. & Jambunathan, R. (1982). Studies on Desi and Kabuli chickpea cultivars: the levels of amylase inhibitors, level of oligosaccharides and *in vitro* starch digestibility. *J. Food Sci.*, **47**, 510–12.

Snedecor, G. W. & Cochran, W. G. (1968). *Statistical Methods*. Oxford and IBH Publishing Co., New Delhi.

Swaminathan, M. (1977). Effect of insect infestation in weight loss, hygienic condition, acceptability and nutritive value of food grains. *Ind. J. Nutr. Dietet.*, **14**, 205–16.