Food Science and Quality Management
ISSN 2224-6088 (Paper) ISSN 2225-0557 (Online)
Vol.21, 2013

Effect of maize weevil (*Sitophilus zeamais* Motschulsky 1855) infestation on the quality of three commercial pastas

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Abstract

The effect of maize weevil (*Sitophilus zeamais* Motschulsky 1855) infestation was evaluated on three pastas under laboratory conditions of 32±2°C temperature and 67±3% relative humidity. Macaroni suffered the highest quantitative loss with the highest number (62) of emerged adults at 2 months after infestation (MAI). However, the highest number (90) of insect at 4 MAI seen in spaghetti was significantly (P< 0.05) higher than 29 observed in noodles. Macaroni had the significantly (P<0.05) lowest final weight (13 g) at 4 MAI. Proximate analysis at 4 MAI revealed that noodles had the highest carbohydrate, dry matter, fibre, crude fat and ash which were significantly higher (P<0.0001) than spaghetti and macaroni. Spaghetti had the highest crude protein which was significantly higher (P<0.0001) than noodles and macaroni. The population of *S. zeamais* at 2 MAI was negatively correlated (r=-0.999, P=0.022) with the final crude fat and positively correlated (r=1.00, P=0.018) with final fibre contents of the pastas. The final weight of pastas at 4 MAI was negatively correlated (r=-0.998, P=0.037) with initial crude protein content of the pastas. The final dry matter of the pasta was positively correlated with the thickness (r=0.998, P=0.044).

Key words: Spaghetti; macaroni; noodles; *Sitophilus zeamais;* infestation; pasta

1. Introduction

Stored product insects infest different agricultural products ranging from the farm gate to industrial products. A number of authors (Adedire 2001; Lale 2002; Babarinde *et al*. 2008a; 2008c; Parkin 2008; Babarinde *et al.* 2013) had reported the menace of insect pest infestation on harvested crop produce or processed products. Babarinde et al. (2008b) reported *Lasioderma serricorne* in a brand of digestive biscuit. Odeyemi et al. (2005) also reported *Tribolium castaneum* in different brands of biscuit. These are indications that processed products that are made of cereals could be attacked by insect pests like *Sitophilus* that are primary pests of cereals.

Sitophilus zeamais Motschulsky is a serious pest of stored cereals. It attacks grains in the field and its infestation is carried into the store where it continues its destructive activities (Haines, 1991). Recently, Babarinde et al. (2008c) reported that *S. zeamais* can infest non-cereals like yam and cassava chips. Owing to the economic importance attached to grains especially cereals in Nigerian agriculture, it became necessary to protect the grains and cereal grain products against damage by insect pests. The population dynamics of *Sitophilus* species is favoured in food materials that have more than 10% water content (Haines, 1991). They affect processed food materials and the nutritive content of the food materials by lowering their components (Bamaiyi et al. 2007). Voracious feeding on whole grains by this insect causes product weight loss, fungal growth, quality loss through an increase in free fatty acids and it can even completely destroy stored grains in all types of storage systems/facilities. Invasion by this primary coloniser may facilitate the establishment of secondary and mite pests and pathogens (Trematerra et al. 2007). *S. zeamais* is an invader and enters packages (e.g. commercial rice or pasta) through existing openings that are created from poor seals, openings made by other insects or mechanical damage (Murata et al. 2008). This tarnishes brand image to the consumers, thus resulting in serious economic damage to food companies.

Under the provisions of the Government of Nigeria's Act No 19 of 1993 (as amended) and the Food Related Products (Registration) Act No. 20 of 1999 and the accompanying Guidelines, no food item may be imported, manufactured, advertised, sold or distributed in Nigeria unless it has been registered by the National Agency for Food and Drug Administration Control (NAFDAC) (Gain Report, 2009). Pasta factories can be infested by insects, leading to negative economic and commercial consequences. Infestations can occur during the storage process in industries or in warehouses, general stores and retail shops already infested by insects feeding on other products (Stejskal et al. 2004; Trematerra et al. 2004; Trematerra and Süss 2006; Murata et al. 2008). To prevent insect contamination, it is important to understand when, where, and how insects invade food products; because olfactory sense in *S. zeamais* plays an important role on the infestation of a food product (Trematerra 2009).

Pasta is available in different colours, shapes and flavours. It is usually made from a part of wheat called semolina. Most commonly associated with Italian cookery, pasta is also an important part of the diet in USA, China, Japan, Korea and other Asian countries. In recent times, it is gaining popularity among school age children's meals in Nigeria. In English speaking countries, the name macaroni is customarily given to specific shape of pasta. In Hong Kong, the local Chinese have adopted macaroni as an ingredient in Hong Kong- style western cuisine. Pasta, in all its forms, is a highly nutritious food (Vernon 1988; Redmon 2008; Spaghetti 2010). Incidentally, much has not been done on the effects of insect's infestation on its quality. Its susceptibility to *S. zeamais* was first reported by Trematerra (2009).

With recent demands for the products in most homes in the developing countries, there is the need to study the effect of insect infestation on their quality as a guide to producers, retailers and consumers for proper handling of the products. Therefore, the objective of this work was to evaluate effect of infestation by *S. zeamais* on weight loss of different pastas and the proximate composition of the products.

2. Materials and Methods

2.1 Culture of *Sitophilus zeamais*

First filial generation *Sitophilus zeamais* was obtained from maize that had been previously infested in the Storage Entomology Unit of Crop and Environmental Protection Laboratory, Ladoke Akintola University of Technology (LAUTECH) Ogbomoso, Nigeria. The culture was raised on maize (var. Tsolo) obtained from Sabo Market, Ogbomoso as described by Babarinde *et al*. (2008a).

2.2 Physical description of the experimented pastas

Spaghetti is a long, cordlike form of pasta. Macaroni, on the other hand, is a kind of product moderately extended short slender tubes, much shorter than spaghetti and hollow. Noodles are other form of pasta with a curly shape. The thicknesses of the pastas were determined with the aid of a vernier caliper and were as follow: spaghetti: 0.17 mm, noodles: 0.22 mm and macaroni: 0.11 mm (having a diameter of 0.22 mm inside the tube). The shapes of the pastas are presented in Plates 1a-c.

2.3 Entomological procedure and proximate analyses

The pastas used were obtained from Sabo Market, Ogbomoso. They were noodles, spaghetti and macaroni. Fifty grammes each of the freshly purchased, insect-free, pastas were taken to the laboratory for proximate analysis in order to determine the following: carbohydrate, dry matter, fibre, crude fat, crude protein and ash. The methods of AOAC (2005) were used for the analyses. Ten mixed-sex *S. zeamais* adults (3 d old) were introduced into 50 g each of the three pastas in 150 ml glass jars. The jars were covered with muslin cloth to allow aeration and prevent entry of other pests. There were eight replicates to make a total of 24 jars. At 2 and 4 months after infestation (MAI), data on population dynamics of *S. zeamais* and final weight of the infested products were taken. This was done by carefully removing the intact products from the adherent powder, but without any physical breakage of the products. At 4 MAI, the leftovers of the infestation of each of the pastas were then packed together and thoroughly stirred with a glass rod to attain homogeneity of the samples. The samples were then taken to the laboratory for proximate analyses using the same methods that were used for the control samples. The analyses for both the control and infested samples were done in four replicates. The results of the analyses of uninfested pastas which served as the control were later compared with those of the infested samples.

2.3 Experimental design and statistical analysis

The experiment on quantitative deterioration of the pastas was set up in a completely randomized design, while that on qualitative deterioration was a 3 x 2 factorial experiment fitted into completely randomized design. Data were subjected to analysis of variance (ANOVA) and standard deviations were indicated to show the variations within the replicates, with the aid of SAS Software Package (SAS Institute 2000). The relationship between the population dynamics of *S. zeamais* and the proximate composition of the pastas was determined by correlation analysis using SPSS Software Version 15 (SPSS 2006).

3. Results

3.1 Effect of different pasta on population dynamics of *Sitophilus zeamais* and quantitative deterioration of pastas

When the pastas were infested with *S. zeamais*, noodles had the lowest number (8.63) of live insects at 2 months which was significantly lower than the numbers in spaghetti and macaroni. There was no significant difference (P>0.05) in the number of dead insect at 2 months in the three pastas. Noodles had the lowest number (28.63) of live insect at 4 months which was significantly lower (P<0.05) than the number (89.75) in spaghetti. There was no significant difference (P>0.05) in the number of dead insect at 4 months in spaghetti, macaroni and noodles. Macaroni suffered the highest loss in weight at 4 months after treatment having a final weight (12.50 g) which was significantly lower (P<0.05) than the final weight of noodles (35.00 g) and spaghetti (30.00 g) (Table 1).

3.2 *Effect of Sitophilus zeamais* on qualitative deterioration of different pastas

The results of the proximate analyses of the pastas after infestation by *S. zeamais* are presented in Tables 2-4. The proximate contents of the infested pastas were significantly lower than (P<0.0001) those of the uninfested, meaning that insect level had significant effect on the proximate analysis of the products. As well, there was an interactive effect of pasta type and insect infestation for all the proximate parameters. When the pastas were infested with *S. zeamais*, noodles had the highest carbohydrate, dry matter, fibre, crude fat and ash which were significantly higher (P<0.0001) than the contents in spaghetti and macaroni (Tables 2, 3 & 4). When pastas were infested with *S. zeamais*, spaghetti had the highest crude protein which was significantly higher (P<0.0001) than noodles and macaroni (Table 4).

3.3 Correlation of *Sitophilus zeamais* population dynamics, weight, thickness and proximate composition of the experimented pastas

The population of *S. zeamais* at 2 MAI was negatively correlated (defined by the equation y = -13.096x + 131.98 and r=-0.999, P=0.022) with the final crude fat of the pastas. Also, the population of *S. zeamais* at 2 MAI was positively correlated (defined by the equation y = -538.07x + 546.78 and r=1.00, P=0.018) with the final fibre contents of the pastas. The final weight of pastas at 4 MAI was negatively correlated (defined by the equation y = -17.044x + 238.55 and r=-0.998, P=0.037) with initial crude protein content of the pastas. The final dry matter was positively correlated (defined by the equation y = 20.56x + 77.127 and r=0.998, P=0.044) with the thickness of the pasta (Fig. 1a-d; Table 5).

4. Discussion

The results indicate that the three tested pastas were susceptible to *S. zeamais* infestation. Of the three products, macaroni suffered highest quantitative loss with highest number of emerged adults after 2 months of infestation observed in the pasta. However, highest number of insects at 4 months was seen in spaghetti. Across the test pastas, noodles appeared to be least susceptible with lowest number of live insect and highest final weight at 4 months after infestation. This implies that when the three pastas are stored and exposed to similar infestation threshold of weevil, the level of damage will be in the following order: macaroni > spaghetti > noodles. The fact that the three pastas were infested indicates that any of them could be a good candidate for cross-infestation of *S. zeamais*; therefore, the need for store hygiene.

Studies on effect of *S. zeamais* infestation on proximate analysis of the pastas indicate that infestation had deleterious effects on all tested parameters. This is because there were significant differences between infested and uninfested samples. This result is in conformity with Babarinde et al. (2010) who recorded that dry matter, ash and crude fibre were significantly reduced with storage period and insect infestation when plantain chips were infested with *Tribolium castaneum* Herbst. Jood et al. (1996) also reported that 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. At the end of the experiments, the highest dry matter, carbohydrate, crude fibre, crude fat and the ash contents were recorded in noodles. However, the highest crude protein was recorded in spaghetti. Although the carbohydrate content of uninfested spaghetti was significantly higher than that of noodles, higher level of carbohydrate in noodles at 4 MAI reveals that spaghetti suffered greater loss of carbohydrate than noodles. Higher percentage of dry matter at 4 MAI could be the reason for the lower damage done to noodles by the insect, since it is known that stored product insects need an optimum level of moisture for their best performance (Haines 1991). The fact that ash component of spaghetti suffered the greatest loss indicates that despite its lower level of quantitative damage, its mineral components were damaged. The basis of qualitative damage might not be solely dependent on insect's feeding but rather a combination of its feeding and deterioration due to release of its waste products.

Appert (1987) and Haines (1991) had reported the release of benzoquinones by *Tribolium castaneum*, which affect the quality of stored product.

The fact that the population of *S. zeamais* at 2 MAI was negatively correlated with crude fat implies that high proportion of crude fat in the pasta suppressed the population dynamics of *S. zeamais.* The population of *S. zeamais* was positively correlated with the final crude fibre content of the pastas, which implies that insects' feeding and reproductive activities led to high crude fibre content. The final weight at 4 MAI was negatively correlated with initial crude protein. This implies that high initial crude protein significantly prevented weight loss due to the infestation of *S. zeamais*. Therefore, increasing the crude protein at the manufacturers' level would both be of nutritional importance to the consumers and curative to infestation by the weevils. The thickness of the pasta was positively correlated with the dry matter; which implies that the thicker a pasta, the lower its hydroscopic tendencies. High hydroscopic tendency predisposes pasta to mould infestation. Therefore, another area that worths infestation is the impact of insect infestation on microbial growth on infested pasta.

In some developing countries, infestation of agricultural produce is ranked to low, moderate and high level. It is only in high level infestation that consumers convert the infested produce to other uses. The reduction in the proximate composition of noodles after insect infestation implies that homes which rely on them would have to provide additional nutrient supplements to supply the depleted nutrients, even in case of low or medium infestation level.

With these discoveries, it is established that *S. zeamais* is a major threat to storage of macaroni, spaghetti and noodles causing both qualitative and quantitative deterioration. This is understandable because the three products are by-products of wheat which is a cereal. Murata et al. (2008) reported that pastas are susceptible to infestation by *S. zeamais* adults. At any point in the marketing channel, infestations can occur during the storage process in industries, warehouses, general stores and retail shops already colonized by insects from other products (Trematerra et al. 2004). The results agree with the findings of Bamaiyi et al. (2007) who reported that cowpea infestation by *Callosobruchus maculatus* led to qualitative deterioration of cowpea grains. Babarinde et al. (2010) also reported that the infestation of plantain chips by *Tribolium castaneum* affected the proximate composition of the chips.

Since *S. zeamais* can infest pasta at either the manufacturing or marketing channel, both manufacturers and marketers have jobs to do in curtailing pest cross-infestation. Manufacturers should ensure that they do not import infested wheat into the ware house and also engage in humanly-safe store hygiene practices. Also, retailers/consumers should adopt store sanitation practices. This will reduce the tendency of cross-infestation of the pastas by stored product pests.

Acknowledgement

The authors are grateful to Prof. C.O. Adedire, Food Storage Technology Programme, Department of Biology, Federal University of Technology, Akure, Nigeria for his useful suggestions and positive criticism of the manuscript. Dr G.O. Kolawole of Department of Crop Production and Soil Science, Ladoke Akintola University of Technology (LAUTECH), Ogbomoso, Nigeria assisted in data analysis with SAS package.

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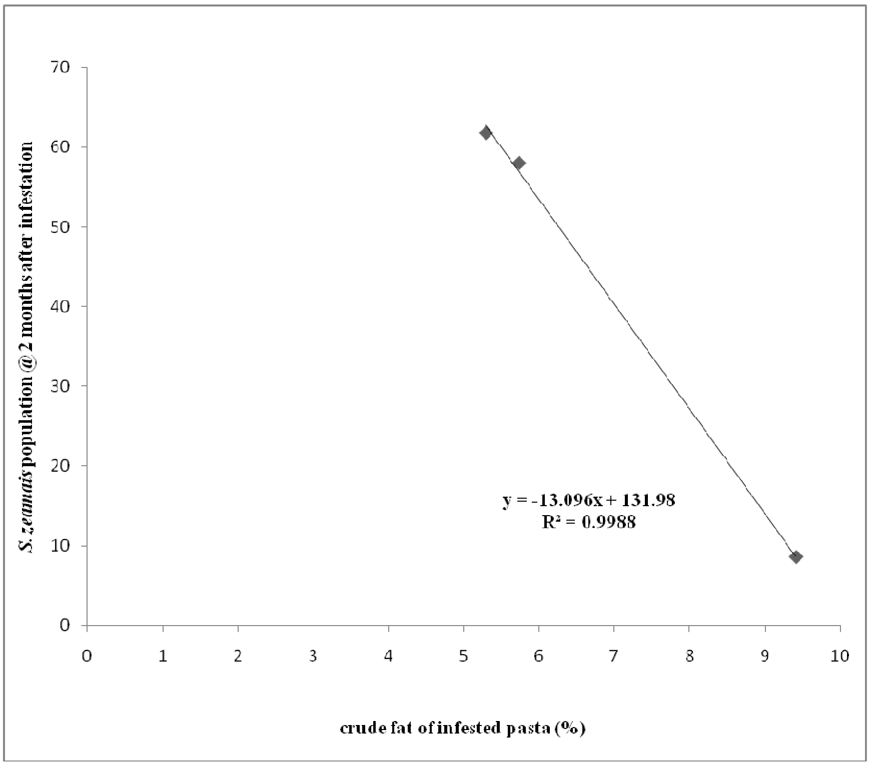

Fig. 1a. Relationship between *S. zeamais* at 2 months after infestation and crude fat of infested pasta

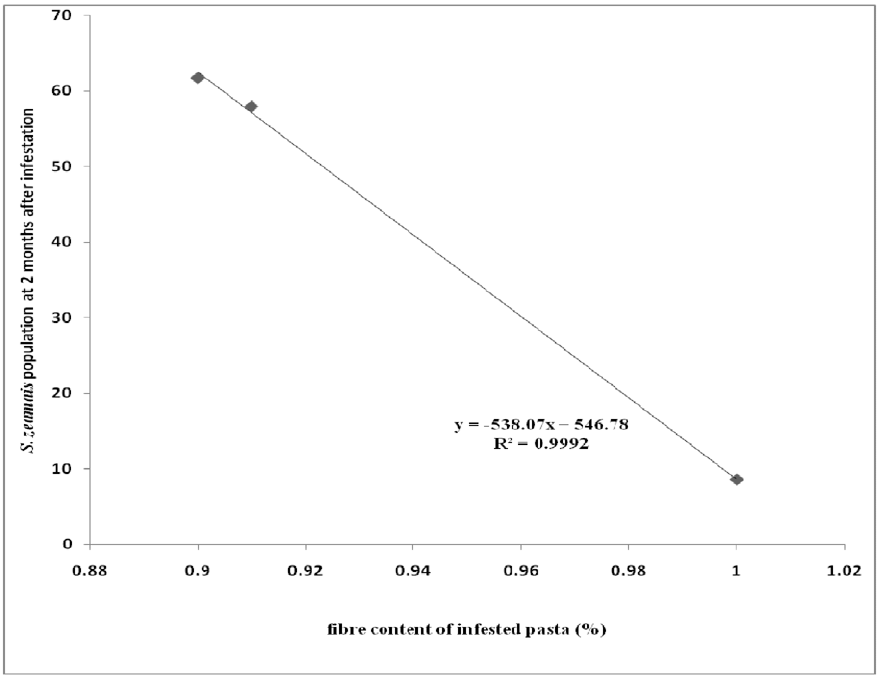

Fig. 1b. Relationship between fibre content of infested pasta and *S. zeamais* at 2 months after infestation

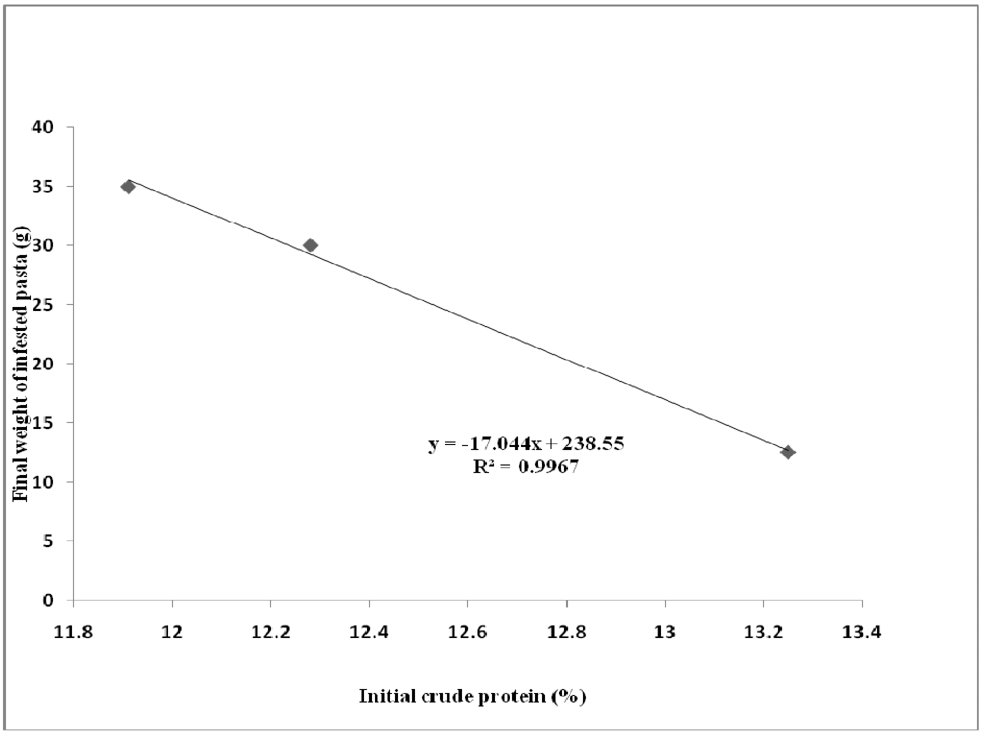

Fig. 1c. Relationship between initial crude protein and final weight of infested pasta

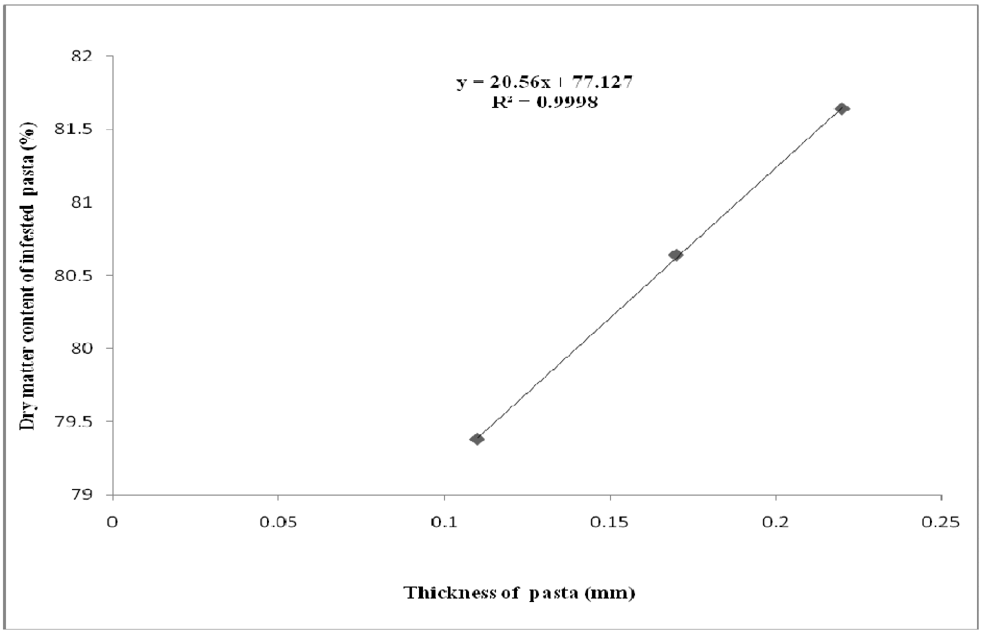

Fig. 1d. Relationship between thickness and dry matter content of infested pasta

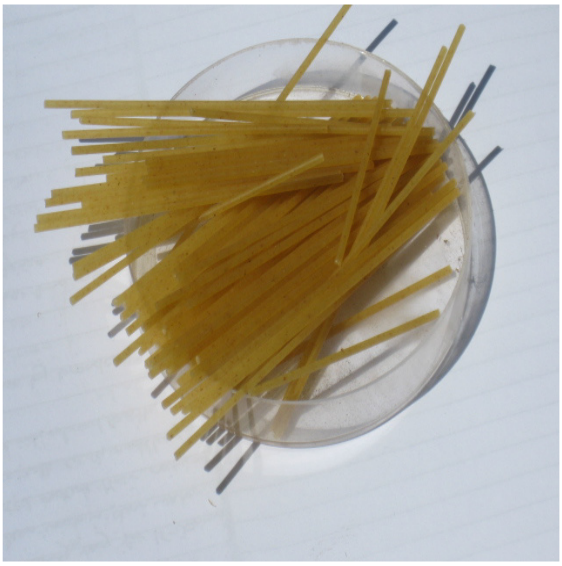

Plate 1a: The experimented spaghetti

Plate 1b: The experimented macaroni

Plate 1c: The experimented noodles

Table 1 Influence of different pasta on *Sitophilus zeamais* population and quantitative deterioration of pasta

Pasta	Live insect at 2 MAI	Dead insect at 2 MAI	Live insect at 4 MAI	Dead insect at 4 MAI	Pasta weight at 4 MAI
Spaghetti	58.00±10.14	2.50±0.68	89.75±5.45	4.13±0.91	30.00±3.78
Macaroni	61.75±8.15	3.00±0.80	58.75±28.65	2.38±1.27	12.50±6.20
Noodles	8.63±2.22	4.50±0.82	28.6±5.63	4.38±1.31	35.00±3.27
LSD	21.70	2.18	54.28	4.04	14.52

MAI = Months after infestation. Data are means of eight replicates ±S.D.

Table 2 Effect of *Sitophilus zeamais* infestation on the percentage carbohydrate and dry matter contents of different pastas at 4 months after infestation

	Carbohydrate		Dry matter	
Pasta	Infested sample	Uninfested sample	Infested sample	Uninfested sample
Spaghetti	21.96 ± 0.2	70.57 ± 0.05	80.64 ± 0.09	90.21 ± 0.02
Macaroni	18.95 ± 0.28	67.66 ± 0.12	79.38 ± 0.05	91.49 ± 0.01
Noodles	29.25 ± 0.35	62.23 ± 0.18	81.46 ± 0.17	91.34 ± 0.02

Carbohydrate
Pasta (P): df =2, 9; F=261.88; P=<0.0001; LSD=0.22
Infestation level (I): df =1, 9; F=11320.46; P=<0.0001; LSD=0.25
Interaction (PxI): df =2, 9; F=164.02; P<0.0001; LSD=0.44

Dry matter
Pasta (P): df =2, 9; F=95.29; P=<0.0001; LSD=0.22
Infestation level (I): df =1, 9; F=25460.6; P=<0.0001; LSD=0.15
Interaction (PxI): df =2, 9; F=147.58; P<0.0001; LSD=0.26

Table 3 Effect of *Sitophilus zeamais* infestation on the percentage ash and crude fat contents of different pastas at 4 months after infestation

	Ash profile		Crude fat profile	
Pasta	Infested sample	Uninfested sample	Infested sample	Uninfested sample
Spaghetti	3.02± 0.04	6.73 ± 0.01	5.73 ± 0.04	7.8± 0.02
Macaroni	3.10± 0.02	6.35 ± 0.01	5.29± 0.02	9.86 ± 0.05
Noodles	3.53 ± 0.10	7.27 ± 0.01	9.41 ± 0.03	14.25 ± 0.02

Ash profile
Pasta (P): df =2, 9; F=526.55; P=<0.0001; LSD=0.05
Infestation level (I): df =1, 9; F=40225.1; P=<0.0001; LSD=0.04
Interaction (PxI): df= 2, 9; F=78.86; P<0.0001; LSD=0.06

Crude fat profile
Pasta (P): df =2, 9; F=40490.9; P=<0.0001; LSD=0.07
Infestation level (I): df =1, 9; F=61902.8; P=<0.0001; LSD=0.04
Interaction (PxI): df =2, 9; F=3012.09; P<0.0001; LSD=0.06

Table 4 Effect of *Sitophilus zeamais* infestation on the percentage crude protein and fibre contents of different pastas at 4 months after infestation

	Crude protein		Fibre	
Pasta	Infested sample	Uninfested sample	Infested sample	Uninfested sample
Spaghetti	9.02 ± 0.17	12.28 ± 0.04	0.91 ± 0.02	2.16 ± 0.01
Macaroni	7.53 ± 0.06	13.25 ± 0.02	0.90 ± 0.02	3.10 ± 0.02
Noodles	7.2 ± 0.08	11.91 ± 0.03	1.00 ± 0.03	2.84 ± 0.01

Crude protein
Pasta (P): df =2, 9; F=63.62; P=<0.0001; LSD=0.10
Infestation level (I): df =1, 9; F=3066.71; P=<0.0001; LSD=0.19
Interaction (PxI): df =2, 9; F=75.28; P<0.0001; LSD=0.30

Fibre
Pasta (P): df =2, 9; F=425.93; P=<0.0001; LSD=0.03
Infestation level (I): df =1, 9; F=23639.4; P=<0.0001; LSD=0.02
Interaction (PxI): df =2, 9; F=510.63; P<0.0001; LSD=0.04

Table 5 Correlation coefficient (r) of population dynamics, final weight, thickness and proximate composition of the experimented pastas

	Pasta type	Thickness	Population @ 2MAI	Population @ 4MAI	Final weight	Initial CHO	Initial DM	Initial ASH	Initial CF	Initial CP	Initial FB	Final CHO	Final DM	Final ASH	Final CF	Final CP	Final FB
Pasta type	1	0.45	- 0.83	-0.99*	0.21	-0.98	0.81	0.58	0.98	-0.27	0. 70	0.69	0.39	0.93	0.81	-0.94	0.82
Thickness (mm)		1	- 0.87	-0.45	0.97	-0.60	-0.15	0.48	0.63	-0.98	-0.32	0.96	0.99*	0.75	0.88	-0.12	0.89
S. seamais population @ 2MAI			1	0.83	-0.72	0.92	-0.35	-0.94	-0.93	0.76	-0.19	-0.97	-0.84	-0.97	-0.99*	0.59	0.99*
S. seamais population @ 4MAI				1	-0.20	0.98	-0.82	-0.58	-0.98	0.26	-0.71	-0.68	-0.34	-0.92	-0.81	0.94	-0.81
Final weight of pasta @ 4MAI					1	-0.38	-0.40	0.92	0.41	-0.99*	-0.55	0.86	0.98	0.55	0.74	0.14	0.74
Initial carbohydrate						1	-0.70	-0.72	-0.99*	0.43	-0.56	-0.80	-0.54	-0.97	-0.90	0.87	-0.90
Initial dry matter							1	0.00	0.68	0.35	0.98	0.14	-0.22	0.54	0.32	-0.96	0.33
Initial ash								1	0.74	-0.94	-0.17	0.98	0.97	0.84	0.95	-0.27	0.95
Initial crude fat									1	-0.46	0.54	0.82	0.57	0.98	0.92	-0.85	0.92
Initial crude protein										1	0.55	-0.88	-0.98	-0.60	-0.78	-0.08	-0.77
Initial fibre											1	-0.36	-0.38	0.39	0.15	-0.90	0.16
Final carbohydrate												1	0.44	0.91	0.98	-0.40	0.98
Final dry matter													1	0.70	0.85	-0.50	0.85
Final ash														1	0.97	-0.75	0.97
Final crude fat															1	-0.56	0.99*
Final crude protein																1	-0.57
Final fibre																	1

* correlation significant at 5% probability