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INSECT INFESTATION OF BILTONG, A SALTED DRIED MEAT PRODUCT CONSUMED IN BOTSWANA

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ABSTRACT: A survey of home and commercial biltong in Botswana showed that hidden infestation by insects undetected before storage affects the quality of biltong. Seventy-nine (79) samples; made up of sixty-one (61) commercial biltong (cb) and eighteen (18) home biltong (hb) were stored under ambient laboratory conditions (temperature range 25 to 30° C, relative humidity range 45 - 70 %) for a period of 3, 6 and 12 months duration; during which samples were examined for hidden infestation. At the end of 3, 6 and 12 months, insect infestation of all the samples was 8.9 %, 17.7% and 68.4%, respectively. The incidence of species after 3 months was: *Dermestes maculatus* (5.1%), *Stegobium paniceum* (2.5%), *Tribolium confusum* (2.5%), *Calliphora* sp. (2.5%), *Oryzaephilus surinamensis* (1.3%), and *Liposcelis* sp. (1.3%). Species predominance in the infested samples was: *Liposcelis* sp. (44.5%)(cb); *S. paniceum* (20%)(cb); *D. maculatus* (16%)(hb); *Acarus siro* (15.5%)(cb); *Calliphora* sp. (2%)(c/hb); *T. confusum* (1)(cb) and *O. surinamensis* (1)(cb). After 6 months, *D. maculatus* was the predominant species (96.6%), caused 72.1% wt. loss, and average feeding residue of 102.9g. It completely destroyed the food product. The weight loss caused by the remaining infesting species was less than 1 % i.e. *Crematogaster* sp.(0.24%), *Plodia interpunctella* (0.62%), *Necrobia rufipes* (0.05%) and *S. paniceum* (0.03%); causing damage to the food product. The incidence of the species in all the samples was: *D. maculatus* (7.6 %)(cb/hb); *Crematogaster* sp. (7.6%)(cb/hb); *P. interpunctella* (7.6 %)(cb/hb); *N. rufipes* (2.5)(hb); *S. paniceum* (1.3)(cb) and *Bracon hebetor* (1.3)(hb). The total average number of insects in all samples was 229. After 12 months of storage, incidence of the species present was: *P. interpunctella* (40%)(cb/hb); *T. confusum* (20%)(cb); *D. maculatus* (12.9%)(cb/hb); *Crematogaster* sp. (11.7%)(cb); *S. paniceum* (7.1%)(cb); *Lasioderma serricorne* (4.7%)(cb/hb); *Callosobruchus maculatus* (2.4%)(cb) and *O. surinamensis* (1.2%)(hb). The predominant species were: *S. paniceum* (49.8%), *P. interpunctella* (14.1%), *T. confusum* (13.5%), *Crematogaster* sp. (12.1%), *L. serricorne* (5.4%), *D. maculatus* (4.4%), *C. maculatus* (0.6%) and *O. surinamensis* (0.07%). Even though *S. paniceum* was the predominant species in commercial biltong, *P. interpunctella* had the highest per cent incidence in both commercial and home biltong samples. The total insect counts in infested samples were 200 (3 months), 1144 (6 months) and 1452 (12 months); indicating increase in insect numbers with longer storage period. Symptoms of biltong damage over the period have been given. Hidden infestation undetected during storage of biltong could create infestation problem.

Key words: Biltong, hidden infestation, damage, insect species, *Dermestes maculatus*

INTRODUCTION

Biltong is an air dried, raw and mostly salted and spiced ready to eat meat product comprised of thin strips that is consumed in Southern Africa. It is produced and consumed to a large extent in Botswana (MATSHEKA *et al.*, 2014) and is similar to the American jerky (VAN DEN HEEVER, 1970), but it is indigenous to South Africa. The product was developed by the early Dutch settlers as a way of preserving meat

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(MATSHEKA *et al.*, 2014). Currently biltong is utilized as food product in many countries including the United Kingdom, Australia, Portugal and the United States, partly due to emigration of South African citizens (ATTWELL, 2003; NAIDOO and LINDSAY, 2010). Botswana, as one of the leading Meat producers is well known for quality biltong production. During the hunting season, Venison biltong is found in abundance. It is more convenient to transport dried meat to distant destinations for storage and use throughout the year and therefore, the most common form of preserved meat in Botswana for a long time. This situation is more prevalent in rural areas where modern methods of food preservation such as the use of refrigerators are either lacking or unaffordable. Hunter-gatherers like the San use biltong extensively due to its reduced weight, ease of preservation and long-shelf life. Biltong is also utilised by urban dwellers, where it is primarily obtained from shops. Presently, there is commercial biltong making machines known as biltong makers, which can produce even 5 kg of biltong at a go (KRIJGER, 2005). Commercial biltong is popular and is highly priced in South Africa and Botswana. Most commercial biltong makers generally follow the same procedure when making biltong. The differences mainly come in the additives and the length of drying the biltong. In commercial production, some fans and ovens are used to dry the biltong (STATHAKIS, 2000). The making of traditional or homemade biltong in Botswana on the other hand involves cutting up of the meat mostly in the open air and without too much hygienic concern, and then salting the meat. The amount of salt used is determined by eye and depends on the person applying it; as a result the amount of salt applied varies among different biltong makers. After this, follows air-drying by hanging the meat on trees branches, but is mostly done outside. This makes homemade biltong to be highly vulnerable to infestation by insect pests. Sacks are normally used for storing homemade biltong. Homemade biltong is still widely produced locally.

There have been concerns about various quality aspects of biltong before reaching the consumer and the need to effect improvement. For instance, it has been found from survey of biltong in Botswana that hidden infestation (i.e. undetected insects or mites present in stored foods) before storage affects the quality of biltong. The quality of biltong is an essential factor in the world market. Consumers would like products that are free from insect infestation, not mouldy nor improperly dried or processed and which meet the expected organoleptic properties. Insect infestation, therefore, is a major contributor to the quality deterioration of biltong. Considerable physical and nutritional losses are incurred with infested biltong. When insects are found in stored biltong even in small numbers, it is necessary to recognise that remedial action will be necessary. Today not much is known about hidden infestation of biltong. Therefore, we determined hidden infestation in commercial and homemade biltong bought from selected shops and local markets in Botswana.

MATERIALS AND METHODS

Samples of biltong ranging in weight from 100-300 g were bought from shops and local markets in Botswana and placed in one-litre glass kilner jars (85 mm diameter, 165 mm deep.). Each jar was covered with a muslin cloth held in place by a metal screw ring. The muslin cloth prevented cross infestation from one sample to the other and ensured that insects which emerged remained in each jar. The jars containing the biltong were kept in the laboratory under ambient conditions (temperature range 25 to 30° C, relative humidity range 45 - 70 %) for 12 months. The biltong samples in each jar were examined for insect infestation after three, six and 12 months. At each assessment time, samples were sieved using standard sieve sets of varying aperture (75μm-200μm) and insects recovered from the sieves were identified and the numbers recorded. In addition the number of larval exoskeletons, weight of remaining biltong samples, weight of feeding residue, weight of associated insects, weight loss of each sample and the visual quality of samples at the end of each storage period were determined. The biltong samples were placed in the jars again for a further storage period. Species incidence was assessed by using the formula: n/N x 100, where n is the number of infested samples and N is the total number of samples. Species predominance was determined using the number of insects of a species in all the samples, divided by the total number of insects of all species in the infested samples expressed as percentage. Seventy-nine (79) samples; made up of sixty-one (61) commercial biltong (cb) and eighteen (18) home biltong (hb) were utilized for experimentation. Experiments were conducted from January 2005 to January 2006.

RESULTS AND DISCUSSION

Hidden infestation of biltong: Insects in biltong samples due to hidden infestation were recorded after three months of storage period (Table-1). Species incidence recorded were *Dermestes maculatus* (5.1 %) > *Stegobium paniceum* (2.5%), *Tribolium confusum* (2.5%), *Calliphora* sp. (2.5%) > *Oryzaephilus surinamensis* (1.3%), *Liposcelis bostrichophila* (1.3%) and mite *Acarus siro* (1.3%). Species predominance can be summarized as: *L. bostrichophila* (44.5 %)(cb) > *S. paniceum* (20%)(cb); *D. maculatus* (16%)(hb); *A.siro* (15.5%)(cb); *Calliphora* sp. (2%)(c/hb); *T. confusum* (1%)(cb) and *O. surinamensis* (1%)(cb). Thus *L. bostrichophila* and *S. paniceum* were the predominant species in commercial biltong and *D. maculatus* was the predominant species in home biltong. The mite *A. siro* was present in commercial biltong.

Table-1: Hidden insect infestation of biltong detected after three months of storage

Insect/ Mite Sp.	Number of infested samples Home biltong	Commercial biltong	Av.No. insect/mite per sample	Species incidence (%)μ, N=79	Species predominance (%)α.
Dermestes maculatus	4	0	32	5.1	16
Stegobium paniceum	0	2	40	2.5	20
Tribolium confusum	0	2	2	2.5	1
Oryzaephilus surinamensis	0	1	2	1.3	1
Liposcelis botrichophila	0	1	89	1.3	44.5
Calliphora sp.	1	1	4	2.5	2
Acarus siro	0	1	31	1.3	15.5
Total	5	7	200	16.5	100

Summary: Number of samples (including mixed infestation) = 07; Total number of samples = 79 & per cent infestation = 8.9; μ = Incidence = number of infested samples/total number of samples expressed as percentage; α = Species predominance = number of insects of a species in all the samples/total number of insects of all species in infested samples expressed as percentage; N = Total no. of biltong samples examined.

Mite in stored product is always associated with high moisture content. The blowfly, *Calliphora* sp. infestation could have started from the drying stage of the biltong, since the fly infests products with high moisture content but can not survive in storage when the moisture content of the product is low. Its development to the adult stage in the product indicated that the infested sample in which it developed was still high in moisture content. The total average number of insects in all samples was 200.The insects were detected from thirteen [5 home biltong (hb), 8 commercial biltong (cb)]. However due to mixed infestation (i.e. containing more than one species) per sample in some cases, the summary (Table-1) of the hidden infestation shows the actual number of infested samples including mixed infestation was seven (7) giving the actual hidden infestation out of 79 samples as 8.9% after 3 months storage period.

Insect numbers and damage caused to biltong due to hidden infestation after 6 months storage (Table-2) showed that *D. maculatus* was the predominant species (96.6%), caused 72.1% wt. loss, and average feeding residue of 102.9g. It completely destroyed the food product, occurring in 6 samples (5 home biltong, 1 commercial biltong). The weight loss caused by the remaining infesting species was less than 1 % i.e. *Crematogaster* sp.(0.24%), *Plodia interpunctella* (0.62%), *Necrobia rufipes* (0.05%) and *S. paniceum* (0.03%); causing damage to the food product.The incidence of the species in all the samples was: *D. maculatus* (7.6 %)(cb/hb); *Crematogaster* sp. (7.6%)(cb/hb); *P. interpunctella* (7.6 %)(cb/hb); *N. rufipes* (2.5)(hb); *S. paniceum* (1.3)(cb) and *Bracon hebetor* (1.3)(hb). The total average number of insects in all samples was 229. Observation showed one sample with *Crematogaster* sp. and another sample with *P. interpunctella* infestation were found to be mould. Insects have been reported to spread fungal spores in and on stored mouldy food products, emphasizing the importance of insect-mould interaction with regard to food safety and organoleptic aspects. Due to mixed infestation (i.e. containing more than one species) per sample in some cases, the summary (Table-2) of the hidden infestation based on the actual number of infested samples including mixed infestation was fourteen (14) giving the actual hidden infestation out of 79 samples as 17.7% after 3 months storage period.

Table-2: Insect numbers and damage caused to biltong due to hidden infestation after 6 months of storage

Insect Sp.	**No. of infested samples** Home biltong	Comm. biltong	**Av. No. insects / sample**	**Av. Wt. Insects (g)**	**Av. Wt. Biltong residue (g)**	**Av. Wt. Feeding (g)**	**% Wt. loss**	**% sp. Incidence**	**% sp. Predominance**	**Quality biltong**
Dermestes maculatus	5	1	221	10.34	38.5	102.97	2.1	7.6	96.6	Dt.
Cremato-gaster sp.	4	2	4.7	0.07	132.2	0.3	0.24	7.6	2.5	Dam.
Plodia Interp-unctella	3	3	1	0.05	122.5	0.5	0.62	7.6	0.5	Dam.
Necrobia rufipes	2	0	1	0.04	134.4	0.05	0.05	2.5	0.2	Dam.
Stegobium paniceum	0	1	1	<0.04	140.4	0.04	0.03	1.3	0.1	Dam.
Bracon hebetor@	1	0	1	<0.02	142.1	*	*	1.3	0.1	Dam.
Total	**15**	**7**	**229**	**10.56**	**710.1**	**103.79**	**73.05**	**27.9**	**100**	

Summary: Number of samples (including mixed infestation) = 14
Total number of samples = 79 & per cent infestation = 17.7; Dt= destroyed, Dam. = damaged
***= negligible, a= biltong sample remaining after infestation, 2 = Parasitoid**

Number of insect collected from biltong due to hidden infestation after 12 months (Table-3) revealed that incidences of the various species were as *P. interpunctella* (40%)(cb/hb); *T. confusum* (20%)(cb); *D. maculatus* (12.9%)(cb/hb); *Crematogaster* sp. (11.7%)(cb); *S. paniceum* (7.1%)(cb); *Lasioderma serricorne* (4.7%)(cb/hb); *Callosobruchus maculatus* (2.4%)(cb) and *O. surinamensis* (1.2%)(hb). The predominant species in the infested samples were: *S. paniceum* (49.8%), *P. interpunctella* (14.1%), *T. confusum* (13.5%), *Crematogaster* sp. (12.1%), *L. serricorne* (5.4%), *D. maculatus* (4.4%), *C. maculatus* (0.6%) and *O. surinamensis* (0.07%).

Even though *S. paniceum* was the predominant species in commercial biltong, *P. interpunctella* had the highest per cent incidence being found in both commercial and home biltong samples. *T. confusum* was the third predominant species and has the second highest incidence after *P. interpunctella*, hence its importance in biltong. The total average number of insects per sample was 187, while total insect count in all the infested samples was 1452. The actual number of infested samples (including mixed infestation) was 54, of 79 samples, recorded hidden infestation 12 months after storage as 68.4%.

Table-3: Number of insect in biltong due to hidden infestation after 12 months of storage

Pest sp.	Number of infested samples		Av. No. insect/ sample	Species incidence (%)μ	Species predominance (%)α
	H-Biltong	C-Biltong			
Dermestes maculatus	8	3	5.8 **(64)***	12.9	4.4
Stegobium paniceum	0	0	120.5 **(723)**	7.1	49.8
Tribolium confusum	0	17	11.5 **(196)**	20	13.5
Oryzaephilus surinamensis	1	0	1.0 **(1)**	1.2	0.07
Cremsatogaster sp.	0	10	17.5 **(175)**	11.7	12.1
Plodia interpunctella	5	29	06.0 **(205)**	40	14.1
Lasioderma serricorne	1	3	19.8 **(79)**	4.7	5.4
Callosobruchus maculatus	0	2	4.5 **(9.0)**	2.4	0.6
Total	**15**	**70**	**186.6 (1452)**	**100**	**100**

Summary: Number of samples (including mixed infestation) = 54; Total number of samples = 79 & per cent infestation = 68.4; Dt= destroyed, Dam. = damaged; μ = Incidence = number of infested samples/total number of samples expressed as percentage; α = Species predominance = number of insects of a species in all the samples/total number of insects of all species in infested samples;
*** = Figures in parentheses denote numbers of insects counted.**

The list of insects and the damage they cause in biltong after 3, 6, and 12 months storage (Table-4) revealed that the major insect species recorded due to hidden infestation were the beetles *viz.*, *D. maculatus*, *S. paniceum*, *L. serricorne*, and *T. confusum*. The symptoms include damage to biltong by insects, making the product to be hollowed in patches internally and externally, with a lot of larval cast skins (exoskeletons) and hairs (spines), and holed due to boring and feeding by insect pests. A sharp odour emanates from heavily *D. maculatus*-infested biltong. *D. maculatus* is an important storage pest of animal products in Africa (ALLOTEY, 2003), is associated with biltong. Moth infestation leads to webbing of the product. The insect pest composition of biltong from shops and local markets is complex and is influenced by inadequate processing, drying and storage practices. Insect species recorded on stored biltong from the present study included: *D. maculatus*, *S. paniceum*, *P. interpunctella*, *Crematogaster* sp., *L. serricorne, T. confusum, N. rufipes, Liposcelis* sp., *O. surinamensis, Calliphora* sp. (during processing, but carried into storage), *C. maculatus, L. serricorne and* the mite *A. siro.*

Exposed biltong is highly susceptible to insect and mite attack and its moisture content may affect the degree of susceptibility. Insect infestation of biltong leads to loss of weight, quality or reputation. Even when biltong samples are not infested, it is possible for infestation to be picked at the time of processing, drying and packaging. Such a situation can lead to biltong being damaged by hidden infestation. Health inspectors in routine inspection, miss all, but the obvious insects on the biltong.

Table-4: Symptoms of damage associated with hidden infestation of biltong after 3, 6 and 12 moths of storage

Insect sp.; Family: Order	Damage symptoms	% incidence 3 / 6 / 12 months (Average)	Pest status	Beltong type
Dermestes maculatus; Dermestidae: Coleoptera	Feeds inside/outside; mass larval cast skins; mass faecal pellets/frass; mass feeding residue; irregular holes/ cavities; larval hairs (setae); severe damage:-mass insect parts and feeding residue; both adults and larvae feed.	5.1 7.6 12.9 **(8.5)**	Major	C/H
Stegobium paniceum; Anobiidae: Coleoptera	Round holes on surface; mass feeding residue; cast skin/ insect parts; larvae covered with food particles; feeding severe on less compact side; damage mainly by larvae	2.5 0.0 7.1 **(3.2)**	Major	C
Lasioderma Serricornae; Anobiidae: Coleoptera	As in case of *S. paniceum*	0.0 0.0 4.7 **(1.6)**	Major	C/H
Tribolium confusum; Tenebrionidae: Coleoptera	Feeds inside/ outside; irregular feeding holes/ cavities; mass larval cast skins; both adult & larva feed	2.5 0.0 20.0 **(7.5)**	Major	C
Oryzaephilus Surinamensis; Silvanidae: Coleoptera	Feeds inside/ outside; damage less severe; both adult larva feed; contamination with faecal pellets; cast larval skins & insect parts	1.3 0.0 1.2 **(0.8)**	Minor	C/H
Callosobruchus maculatus; Bruchidae	Larvae feed, damage less severe; contamination with faecal pellets; cast larval skins & insect parts; adults do not feed	0.0 0.0 2.4 **(0.8)**	Minor	C
Necrobia rufipes; Cleridae: Coleoptera	Larvae feed & bore into biltong; eat other insects in biltong; adult feeds on surface; contamination with body parts & faecal pellets	0.0 2.5 0.0 **(0.8)**	Minor	H
Plodia interpunctella; Phycitidae: Lepidoptera	Larvae feed inside/outside; contamination with silk/ webbings; round faecal pellets; larval galleries; adult do not feed	0.0 7.6 40.0 **(16.9)**	Major	C/H
Crematogaster sp.; Formicidae: Hymenoptera	Mostly associated with commercial biltong; damage less severe; dead insect parts; sometimes found in large number	0.0 7.6 12.7 **(6.8)**	Major	C
Bracon hebetor Braconidae: Hymenoptera	Parasitic wasp which attacks larvae of beetles & moths; regarded as pollutant in bildong; dead body parts contaminate food	0.0 1.3 0.0 **(0.4)**	Minor	H

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Table 4.Contd...

Liposcelis bostrichophilus Liposcelidae : Psocoptera	Feeds inside/ outside; sometimes found in large number, contaminate with body parts; damage not severe	1.3	0.0 **(0.4)**	0.0	Minor	C
Callipohora sp. Calliphoridae: Diptera	Infestation starts at drying stage; adults lay eggs in product; larvae feed on the product; adults emerge before product is properly dried; contamination with body parts	2.5	0.0 **(0.8)**	0.0	Minor	C/H
Acarus siro; Tyroglyphidae: Acarina	Infestation in product at high moisture content/ improperly fried; contamination with body parts	1.3	0.0 **(0.4)**	0.0	Minor	CH

C = Commercially prepared biltong, H= Homemade biltong

Detection of hidden infestation calls for more elaborate methods than visual inspections, which only assesses by facial appearance and therefore, incomplete for those insects which spend a part of their life cycle within the biltong. There is still reliance upon visual inspection by health inspectors in shops and market places where biltong can be obtained even though this method is not entirely accurate. Symptoms of damage to biltong caused by major pest species like *D. maculatus*, *S. paniceum*, *T. confusum* and *P. interpunctella* in the present study (Photos A, B) found damage to biltong by insects, making the product hollowed in patches internally and externally, sometimes with a lot of larval cast skins (exoskeletons) and hairs (spines) in the product depending on the species e.g. as caused by the larvae of *D. maculatus*, or holed due to boring and feeding by grub-like larvae of *S. paniceum* and *L. serricorne,* or with feeding powdery residues in the product in all cases and with moth infestation, a trail of fine thread, can be seen on the product caused by the wandering larvae. In severe infestation, there would be webbing of the product, e.g. as caused by *P. interpuntella*.

Biltong samples, which are not properly processed and dried, become mouldy due to high moisture content and this condition affects the quality of the product (MPUCHANE *et al.*, 2003). Currently, it appears that most consumers prefer the moist biltong with water activity (Aw) ranging from 0.85- 0.93 (ATTWELL, 2003; NAIDOO and LINDSAY, 2010). The situation becomes more pronounced when the mouldy biltong is infested due to hidden infestation. Insects and moulds present in biltong grow and cause characteristic spoilage. Through their metabolic activities insects can create areas of high humidity and temperatures as well as release carbon dioxide and water (PRAKASH *et al.*, 2003), which are conducive for fungal growth and multiplication. Under tropical conditions most insects breed very quickly with life cycles, being completed in a few weeks with each female laying a large number of eggs. Thus their success lies in their short development periods, fast reproduction potential and negatively long adult life span (ALLOTEY, 1991).

P. interpunctella and *T. confusum* were found in mouldy samples in the present study. Biltong infested with insects and fungi lose weight and nutritional value, elements necessary for its market quality and food value. Insects also serve as mobile source of fungal metabolites and mycotoxins (toxic metabolites produced by various moulds) (ALLOTEY and ODAMTTEN, 1996a). Mycotoxins cause various acute and chronic illness that affect the nervous system, the cardio-vascular system and digestive and pulmonary systems. Certain mycotoxins are carcinogenic (SIMPANYA *et al.*, 2001). To prevent contamination by insects and toxigenic moulds and subsequent mycotoxins production in the product, it is necessary to dry biltong rapidly to safe moisture content and maintain that level, to reduce the attraction of storage insect pests.

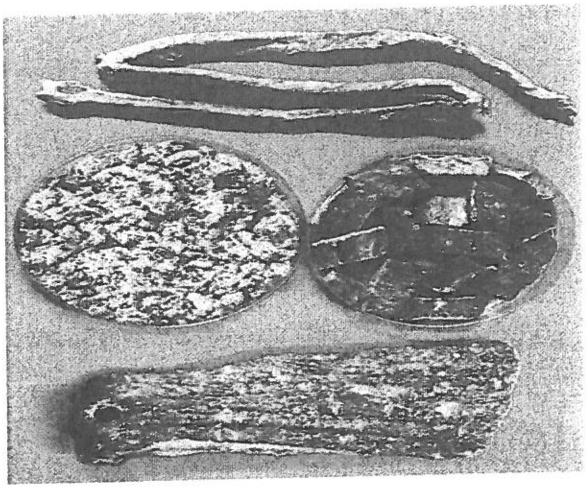

Photo-A: Biltong types, home biltong (top), shredded biltong (centre left), biltong chips (centre right) and commercial biltong (bottom)

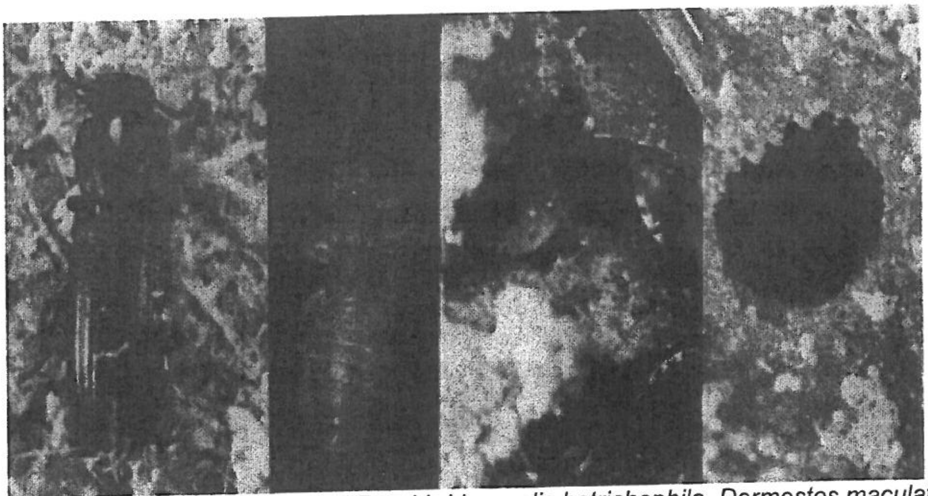

Photo-B: *Tribolium castaneum*, Psocid, *Liposcelis botrichophila*, *Dermestes maculatus* and holed biltong

The latter infestation lead to physical damage, contamination with faecal pellets, cast skins etc. and weight loss of biltong. A strategy therefore to prevent and control the formation of mycotoxins should include the following actions and should be applicable by semi-qualified operators.

i. Identification of the nature and extent of the hidden infestation/ moulds/ mycotoxins problem.
ii. Introduction of improved methods of handling and quality control,
iii. Use of detoxification procedures.

iv. Establishment of work groups from the Ministry of Health, Agriculture and Livestock sectors, on the dangers presented by mycotoxins, and

iv. Support and training of local biltong processors.

Losses in storage are of multiple characters, including loss in weight, quality, nutritive and market values. Each of these types of losses may have different significance, which varies with people, time, and place and with loss assessment methods and techniques. The losses are not limited to technical and physical factors only. The socio-economic realities do play an important role particularly in developing countries. A precise, comprehensive and uniform method for expressing storage losses is yet not available. The process of determining weight changes has not been given due consideration for all the variants *viz*.., moisture from atmosphere, moisture through insect metabolism, heating, moisture migration and presence of insect contaminants and socio-economic factors (PRAKASH and RAO, 2003).

The present study showed that at the end of 6 months storage period of biltong, there was 17.7% hidden infestation of all the samples, with an overall 4.6% average wt. loss of biltong. While the average wt. loss of the infested samples was 26%. Hidden infestation has been considered significant during storage of stored products (ALLOTEY and ODAMTTEN, 1996b; ALLOTEY *et al*., 2017) and grow under low moisture content lower than 20%. Those species requiring higher moisture (m.c.) in stored commodities for completion of development such as mites, Psocoptera and mycetophagous beetles are seldom of primary pest status and can be dealt with by measures, which lower the moisture content of the commodity (BELL, 2003). Nevertheless and notwithstanding the need for strategic disinfestations, for example by fumigation, and because of resistance, residues, and consumer attitudes associated with chemicals, control requires the in-built permanency of physical measures. This must be integrated if necessary with biological and other control although frequently, for whatever reason, it may include chemical controls.

Suggested insect pest management strategies

Even though we may be aiming immediately at applied control because of the market demand for high quality biltong, there is no justification for ignoring basic biological and behavioural research that must underpin long-term control. Control of insect pests of home made stored biltong should start at the drying stage by ensuring that the sacks used to store biltong are disinfested through boiling for at least 30 minutes, and drying in the sun for at least two hours before usage. Solar heaters can be used to disinfest biltong before storage. The solar heater can be constructed by spreading home made biltong evenly on black polythene material; and covering it with a transparent polythene material. The sides of the transparent polythene should be folded over the black polythene to create an envelope, which traps enough heat from the sun to raise the temperature within the envelope to 54-60° C within three hours. The temperature attained within this short period is high enough to destroy all developmental stages of insect pests infesting biltong prior to storage (ALLOTEY *et al*., 1998).

CONCLUSION: A number of insect pests are associated with biltong which may not be detected at the beginning of storage. This hidden infestation can be prevented or avoided if 1) the biltong is well dried and hygienic and physical control measures (e.g. application and sustained heat of 55-60°C in the biltong storage rooms for 2-3 hours) are implemented. 2) Effective legislation, monitoring and education of the vendors, consumers and law enforcement officers (include HACCP principles) are applied.

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