

COMPARATIVE EFFICACY OF DIFFERENT MODIFIED ATMOSPHERES IN THE CONTROL OF COWPEA WEEVIL (*CALLOSOBRUCHUS MACULATUS* (FAB.)) AND BAMBARA GROUNDNUT WEEVIL (*CALLOSOBRUCHUS SUBINNOTATUS* (PIC)) ON TWO STORED LEGUMES

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ABSTRACT

The effects of three different combinations of modified atmosphere (MA) treatments, 70% CO₂ in air and 1.0% O₂ in N₂ at 25±2°C and four relative humidities (r.h) (10±3%, 34±2%, 70±2% and 90±3%); three high temperatures (40°C, 45°C and 50°C) at a constant, low humidity (30%) and lastly 100% CO₂ at 32°C and 70% r.h were evaluated on the oviposition, development and mortality of the bruchids. Review of the literature showed that mortality of eggs and adults of the bruchids in 70% CO₂ in air and 1.0% O₂ in N₂ was higher at 10±3% and 34±2% r.h. A significantly higher percentage of the adults of both species introduced for oviposition died on seeds exposed to 50°C after only 2 hours exposure time. All the young larvae of both species died within an exposure period of 48 hours in 100% CO₂ at 32°C and 70% r.h. In contrast, the older larvae required 78 hours exposure time of the same treatment for 100% mortality. Results of the review also indicated that modification of atmospheric factors have enormous influence on egg laying and development of these bruchids in grain legumes and same could be employed as effective, safe and residue-free means of controlling the pests.

KEYWORDS: *Callosobruchus maculatus*, *Callosobruchus subinnotatus*, Larvae, Modified atmosphere.

INTRODUCTION

Grain legumes are among the cheapest sources of staple dietary protein in many tropical and subtropical countries of the world, especially where access to animal protein is limited (Mbata and Reichmuth, 1996). They are important in the diets of rural communities in tropical Africa and Asia as rich sources of protein (Lale and Vidal, 2003). They are also widely cultivated and eaten (Ohiagu, 1986), and the most important producing areas in Nigeria being located in the savanna (Agboola, 1979), but the crops are also grown in some parts of the more humid south (Lale and Vidal, 2003). These grain legumes are, however, susceptible to different beetles of the family *Bruchidae* in storage (Lale and Vidal, 2003). The cowpea seed bruchids, *Callosobruchus maculatus* (F.) is ranked as the principal post-harvest pest of cowpea (Jackai and Daoust, 1986; Ogunwolu and Odunlami, 1996; Lale and Vidal, 2003), while Bambara groundnut is sometimes infested concurrently in West Africa by *Callosobruchus subinnotatus* (Pic) and *C. maculatus* (Pevett, 1966; Mbata, 1991; Lale and Vidal, 2003). However, *C. subinnotatus* is the major storage insect pest of Bambara groundnut (Jackai and Daoust, 1986; Mbata, 1991; Haines, 1991; Mbata et al., 1996).

The damage inflicted to these grain legumes is caused by the larvae feeding inside the seeds. Severe infestation can lead to losses in weight up to 30% and render the commodity

unacceptable for human consumption (Tylor, 1977; Mbata et al., 1996). Up to 40% loss in weight of stored Bambara nuts due to infestation by *C. subinnotatus* has been observed under small farmer storage and in markets stores in Kano, Northern Nigeria (Mbata, 1991; Mbata et al., 1996).

Chemical control of the bruchids such as dusting with insecticides like pirimiphos-methyl, fenitrothion and synthetic pyrethroids or fumigation with phosphine and methyl bromide are effective (Cardona and Karel, 1990; Mbata et al., 1996). However, inherent problems associated with the use of chemical insecticides such as development of resistance by the insect pests, environmental pollution and contamination of grains are inducing scientists to look for alternative means of controlling insect pest population (Bailey and Banks, 1980; Yusuf and Ahmed, 2005).

Controlled atmospheres, otherwise known as modified atmospheres (MA) offer an effective, safe and residue-free alternative to chemical fumigants and protectants for controlling insect and mites infesting stored grains and grain products (Banks and Fields, 1995; Annis and Morton, 1997). MA treatment for stored products protection involved two main methods of producing physiological and biochemical stress in the pest organism (Ofuya and Reichmuth, 2002).

The utilization of MA for bruchids control is based on the knowledge that insects die when exposed to harsh atmospheric factors because of their limited physiological capacity to thermoregulate (Murdock et al., 1997; Lale and Vidal, 2003). Bruchid's eggs, larvae and pupae do not thermoregulate and being immobile are unable to escape from unfavorable environment. Therefore, bruchids living within grains are excellent targets for management using controlled atmospheres (Murdock et al., 1997; Lale and Vidal, 2003).

Effect of Relative Humidity on the Susceptibility of *C. maculatus*:

Humidity influences the survival of insects and dry conditions appear to be generally unfavorable on reproduction of most insects (Gullan and Cranston, 1994). Low humidity conditions adversely affected the development, reproduction and longevity of *C. maculatus* (Howe and Currie, 1964). Dowson (1995) observed that carbon-dioxide induced *anaesthesia* in *C. maculatus* results in reduced fecundity. Jay et al. (1971) indicated that low humidities and MA used together would bring about higher insect mortality within a given exposure time than either factor alone. This review observed that mortality of eggs and adults of *C. maculatus* exposed to 70% CO₂ in air and 1.0% O₂ in N₂ increased as r.h decreased (Table 1). Development time was longest (Table 2), adult longevity shortest (Table 3) and female fecundity lowest (Table 4) at the lowest humidity tested. The review also observed that the combined effect of low r.h and MA adversely affected development, longevity and fecundity of the bruchids than low r.h in normal air. Mortality of larvae and pupae was not significant. This may be because they are protected within the seeds.

Effect of Solar Heat on the Survival of Adults *C. maculatus* and *C. subinnotatus*:

Results of the literature reviewed indicated that exposing adults of the bruchids to a temperature of 50°C, especially for 4 or 6 hours, caused a

significant reduction in the survival of adult *C. maculatus* and *C. subinnotatus* as opposed to 2 hours or less (Tables 4 and 6). There is, as yet, no agreement on the precise mechanism causing death at high temperatures, but changes in lipids, particularly increased fluidity of phospholipid membranes in the nervous system, metabolic rate imbalances, perturbation of ionic activities as well as desiccation have been proposed as possible cause of death at high temperature (Fields, 1992). High temperatures are also known to cause heat stupor (inability to move) and finally death in adult insects (Chapman, 1982). It has also been reported that insects die at low humidities from the effect of desiccation and in many cases low humidities make insects more susceptible to heat (Chapman, 1982; Fields, 1992).

Effect of the Toxicity of Carbon-dioxide to the Developmental Stages of *C. maculatus* and *C. subinnotatus*:

According to the literature reviewed, there was no significant difference between the exposure periods required to obtain 100% mortality among similar stages of the two bruchids. Susceptibility of the larval stages of the bruchids was presented in figures 1 and 2. When the early larval stage was exposed to the inert atmosphere, 100% mortality was recorded after two days of exposure (Fig.1) compared to four days exposure for the late larval stage (Fig. 2). In the tropics where Bambara seeds are infested concurrently or individually by the two bruchids, they can therefore be disinfested by exposing them to 100% CO₂ for six days, since ambient temperatures in these areas are sometimes higher than 30° C. This period of exposure to CO₂ required for 100% mortality in these beetles is shorter than the recommended exposure period of 15 days for disinfesting grains with high CO₂ at commodity temperature of 25 - 90°C (Banks et al., 1990).

Table 1: Computed Abbott mortality of *Callosobruchus maculatus* life stages exposed to 70% CO₂ in air and 1.0% O₂ in N₂ respectively, at 25 ± 2°C and four different relative humidities.

Life Stage	Relative Humidity %	Percentage Mortality ± S. E	
		70% CO ₂ in Air	1.0% O ₂ in N ₂
Egg	10 ± 3	63.4 ± 3.45c	76.2 ± 4.42c
	34 ± 2	51.2 ± 3.22b	62.3 ± 3.78b
	70 ± 2	27.4 ± 2.88a	32.4 ± 3.03a
	90 ± 3	21.0 ± 2.12a	33.4 ± 2.77a
Larva	10 ± 3	46.8 ± 3.46a	33.4 ± 3.03a
	34 ± 2	43.2 ± 4.32a	31.6 ± 3.12a
	70 ± 2	41.4 ± 3.24a	29.6 ± 2.65a
	90 ± 3	42.3 ± 3.21a	30.2 ± 2.32a
Pupa	10 ± 3	43.1 ± 3.46a	34.2 ± 2.68a
	34 ± 2	42.6 ± 3.32a	32.6 ± 3.01a
	70 ± 2	39.2 ± 2.78a	32.1 ± 2.75a
	90 ± 3	41.4 ± 2.75 a	31.4 ± 2.43a
Adult	10 ± 3	74.3 ± 3.56c	80.4 ± 3.33c
	34 ± 2	49.6 ± 2.89b	68.2 ± 3.36b
	70 ± 2	31.0 ± 2.31a	48.6 ± 2.74a
	90 ± 3	29.4 ± 2.46a	50.2 ± 2.43a

Source: Ofuya and Reichmuth (2002).

Table 2: Development period (egg-adult) of *C. maculatus* exposed to normal air, 70% CO₂ in air and 1.0% O₂ in N₂ respectively, at 25 ± 2°C and four different relative humidities.

Relative Humidity (%)	Development Period (Days) ± S.E.	
	Normal Air (70% CO ₂ in Air)	1.0% O ₂ in N ₂
10 ± 3	32.4 ± 0.34ab(a)	39.4 ± 0.22c(c)
34 ± 2	29.2 ± 0.21ab(a)	36.2 ± 0.24b(c)
70 ± 2	27.3 ± 0.24a(a)	32.6 ± 0.19a(c)
90 ± 3	26.2 ± 0.14a(a)	29.8 ± 0.21a(b)

Source: Ofuya and Reichmuth (2002).

Table 3: Longevity of *C. maculatus* exposed to normal air, 70% CO₂ in air and 1.0% O₂ in N₂ respectively, at 25 ± 2°C and four different relative humidities.

Relative Humidity (%)	Longevity (Days) ± S.E.	
	Normal Air (70% CO ₂ in Air)	1.0% O ₂ in N ₂
10 ± 3	4.8 ± 0.19a(b)	2.2 ± 0.89a(a)
34 ± 2	7.6 ± 0.24ab(b)	3.8 ± 0.67a(a)
70 ± 2	9.4 ± 0.37bc(b)	6.8 ± 0.77b(a)
90 ± 3	11.4 ± 0.26c(b)	7.2 ± 0.98b(a)

Source: Ofuya and Reichmuth (2002).

Table 4: Fecundity of *C. maculatus* emerging from exposed eggs, and after 12 h exposure to normal air, 70% CO₂ in air and 1.0% O₂ in N₂ respectively, at 25 ± 2°C and four different relative humidities.

Relative Humidity (%)	No. of eggs laid by adults exposed to atmosphere ± S.E.	
	Normal Air (70% CO ₂ in Air)	1.0% O ₂ in N ₂
10 ± 3	48.6 ± 4.04a(b)	13.2 ± 1.78a(a)
34 ± 2	84.6 ± 3.74b(b)	24.8 ± 1.97b(a)
70 ± 2	90.4 ± 4.47b(b)	43.5 ± 2.01c(a)
90 ± 3	86.2 ± 4.71b(c)	41.5 ± 1.98c(b)

Source: Ofuya and Reichmuth (2002).

Table 5: Mean percentage mortality of *Callosobruchus maculatus* adults exposed to different durations of high temperature.

Temp. °C	Duration of Exposure (h)					Mean
	0	1	2	4	6	
40	0.0a	0.0a	0.0a	0.0a	0.0a	0.0c
45	0.0a	18.8a (3M)*	18.8a (2M,1F)	25.0a (4M)	25.0a (3M,1F)	17.5d
50	6.3a (1F)	87.5b (7M,7F)	100.0b	100.0b	100.0b	75.8e
Mean	2.1f	35.4g	39.6g	41.7g	41.7g	

Source: Lale and Vidal (2003).

Table 6: Mean percentage mortality of *Callosobruchus subinnotatus* adults exposed to different durations of high temperature.

Temp. °C	Duration of Exposure (h)					Mean
	0	1	2	4	6	
40	0.0a	0.0a	0.0a	0.0a	6.3a (1M)*	1.3c
45	0.0a	0.0a	0.0a	6.3a (1M)	12.5a (1M,1F)	3.8c
50	0.0a	12.5a (2M)	100.0b	100.0b	100.0b	62.5d
Mean	0.0e	4.2e	33.3f	35.4f	37.5f	

Source: Lale and Vidal (2003).

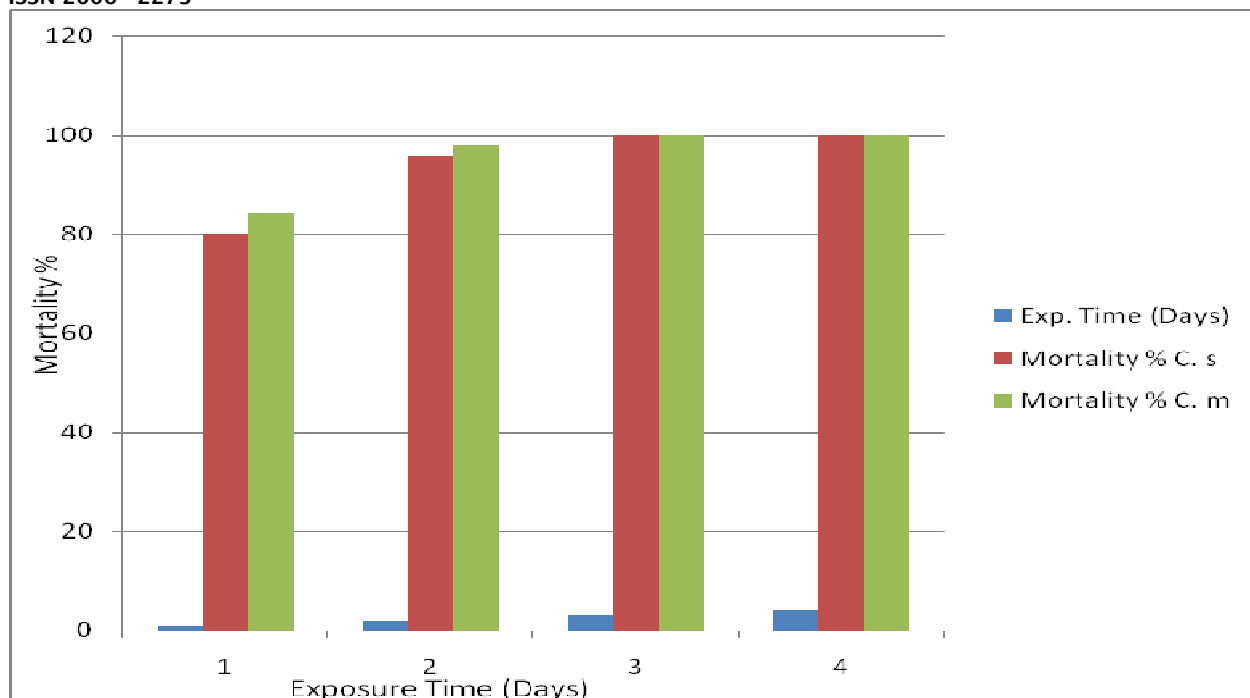


Figure 1: Mortality of young larval stage of the two bruchids exposed to 100% CO₂ (values bearing different letters are significantly different, P < 0.05).
 Source: Mbata *et al.* (1996).

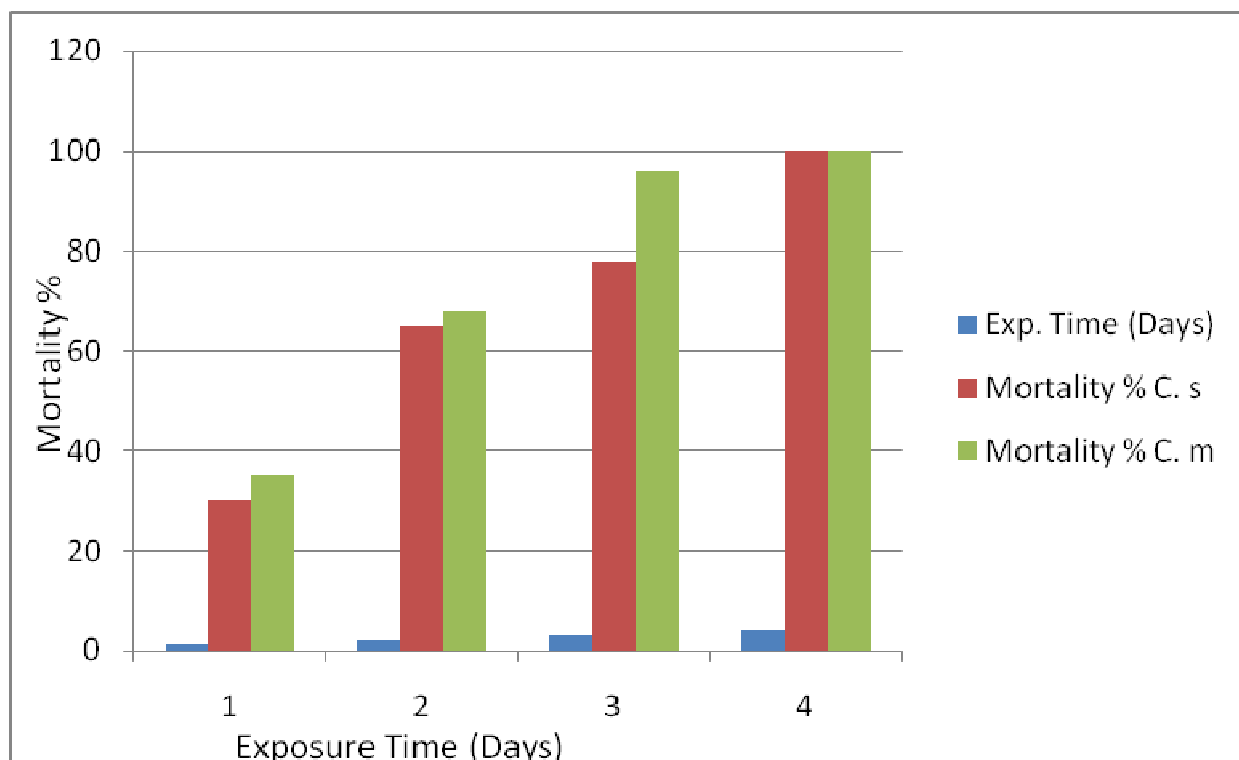


Figure 2: Mortality of late larval stage of the two bruchids exposed to 100% CO₂ (values bearing different letters are significantly different, P < 0.05).
 Source: Mbata *et al.* (1996).

CONCLUSION AND RECOMMENDATIONS

Subsistent farmers do not have the resources to use 'high tech' measures such as environmental manipulation for the control of these bruchids in tropical storage (Lale and Vidal, 2003). In addition, high cost and attendant possible health hazards associated with misuse of chemical insecticides by farmers (Yusuf and Ahmed, 2005) as well as increasing demand for pesticide-free food have prompted efforts to find alternative management options which are environmentally friendly and economically cheaper (Dal-Bello et al., 2001 and Batta, 2003).

Alternatively, controlled atmosphere storage, which involves the alteration of atmospheric factors to levels which are lethal to the stored products pests, retards development of stored products *Coleoptera* and causes mortality of their developmental stages (Sharma et al., 1997; Lale and Vidal, 2003) should be adopted. The use of elevated temperatures at lower relative humidities (such as solarization) is one method which has great potentials for the

management of these insect pests in Nigerian savanna and other tropical countries where there is abundant sunshine virtually throughout the year, but particularly during the hot, dry season (March - May). During this season, daytime temperatures in the open reach 50°C or more and relative humidities are as low as 10 - 20% (Ebeling, 1997 and Sharma et al., 1997).

In view of this, it is therefore recommended that such information should be made available to extension agents for onward transmission to farmers especially the subsistent ones living in rural communities where same could be used for effective, safe and residue-free management and control of storage bruchids infesting grain legumes.

Advisably also, governments should provide storage facilities conforming to MA standards for use by whole sales and retailing grain merchants in large grain markets such as Dawanau grain market in Kano, Muda Lawal in Bauchi and many others scattered throughout the country.

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