

Efficacy of Microwave irradiation on the postharvest control of Cowpea Bruchid, (*Callosbruchus maculatus*) Coleoptera:Bruchidae on stored cowpea

C.O. Echereobia ¹, E.F. Asawalam ^{2*}, K.C. Emeasor ², I.E. Nwana ² and K. Sahayaraj ³

(Put * above the corresponding author and give telephone number, fax number and email ID in the footer)
¹Department of Crop Science and Technology Federal University of Technology Owerri, P.M.B. 1526, Owerri, Imo State, Nigeria,

echereobia@yahoo.com or echereobia@futo.edu.ng

²Department of Plant Health management, Michael Okpara University of Agriculture Umudike, P.M.B. 7267, Umuahia, Abia State, Nigeria.

³Crop Protection Research Centre, Department of Advanced Zoology and Biotechnology, St Xavier's College (Autonomous), Palayamkottai 627 002 Tamil Nadu, India

elechiasw@yahoo.com,

ABSTRACT (ARIAL, BOLD, 11 FONT, LEFT ALIGNED, CAPS)

The efficacy of microwave irradiation against cowpea bruchid at the Crop Protection Research Centre laboratory, St Xavier's College (Autonomous), Palayamkottai India under laboratory conditions (28±2 °C, 70 – 75% RH and 11 : 13h photoperiod) was investigated using mortality, damage assessment, germination test and proximate composition assays. Five pairs of 2 day old *C. maculatus* collected from stock culture were kept in a Petri-dish containing 50 healthy seeds (Ife brown variety) and exposed to microwave irradiation at 100 power level for 0,4,6,8, and 10 minutes. The experiment was conducted using Completely Randomized Design (CRD) replicated five times. Results showed that microwave irradiation significantly ($P \leq 0.05$) increased the mortality of *C. maculatus* when compared with control without adversely affecting the viability and proximate composition of the seeds. The potential use of microwave irradiation as alternative seed protectants against *C. maculatus* on stored cowpea is recommended.

Keywords: [: Cowpea, Cowpea Bruchid, Efficacy, Microwave Irradiation] (Arial, inclined, 10 font, justified)

(Note: 1. Case Reports should follow the structure of Abstract, Introduction, Presentation of Case, Discussion, Conclusion, Acknowledgements, Competing Interests, Authors' Contributions, Consent (where applicable), Ethical approval (where applicable), and References plus figures and/or tables. Abstract (not more than 250 words) of the Case reports should have the following sections: Aims, Presentation of Case, Discussion and Conclusion. Only Case Reports have word limits: Papers should not exceed 2000 words, 20 references or 5 figures. Other Type of papers have no word limits.
2. Review papers may have different headings of the sections and are exempted from following these suggestions.

3. Research Papers and Short Notes should follow the structure of Abstract, Introduction, Methodology, Results and Discussion, Conclusion, Acknowledgements, Competing Interests, Authors' *Corresponding author Email: elechiasw@yahoo.com
+2348039695157

1. INTRODUCTION (ARIAL, BOLD, 11 FONT, LEFT ALIGNED, CAPS)

Cowpea (*Vigna unguiculata* L.(Walp) is a major source of dietary protein and also used as green vegetables in forms of pod and leaves (Sanginga *et al.*, 2003; Allotey *et al.*, 2012). Nigeria is the World's largest producer with an annual production of 2.1 million tons (IITA, 2003).

With its high protein, cowpea is a natural supplement to cereal, root and tuber supplies in African diet (IITA 1989). Insect pests are major constraints to cowpea production (Ogunwolu and Odunlami, 1996; Adedunta and Ofuya, 1998) and post-harvest losses related to insect pest damage are a major problem for smallholder farmers in Nigeria. *Callosobruchus maculatus* is a serious insect pest of stored cowpea. Synthetic insecticides have been used to control this insect pest. However, the problems of many synthetic insecticides which include: high persistence, poor knowledge of application by resource-poor-farmers, high cost, non availability, genetic resistance and hazards to environment and human health have necessitated the search for alternative environmentally safe and sustainable control measures (Akinkulere *et al.*, 2006). The use of irradiation, heat treatments, biopesticides, integrated pest management, use of insect hormones (Follett *et al.*, 2007; Begum *et al.*, 2009) have been employed as alternative control strategies. Gasemzadeh *et al.* (2010) recommended disinfestation method of control against *C. maculatus*. The objectives of this research are to ascertain the effect of microwave irradiation on the mortality of *C. maculatus*, viability of cowpea seeds and proximate compositions of irradiated cowpea seeds.

2. MATERIAL AND METHODS (ARIAL, BOLD, 11 FONT, LEFT ALIGNED, CAPS)

Insect culture:

Stock culture of *Callosobruchus maculatus* was established from infested cowpea seeds purchased from world bank market, New Owerri, Imo State. Insects were reared on susceptible healthy seeds (Ife Brown) kept in plastic containers covered with perforated muslin cloth held in place with tight rubber bands. The culture was maintained under laboratory conditions (28 ± 2 °C, 70 – 75% RH and 11:13h photoperiod) at crop protection Research Centre, St Xavier's College, Palayamkottai, Tamil Nadu, India. Normal, healthy 1-

66 2 day old male and female *C. maculatus* were used for the experiment. Sexing was done following the
67 methods of Halstead (1963).

68 **Microwave Irradiation Bioassay**

69 Five pairs of 1- 2 day old *C. maculatus* collected from stock culture were kept into Petri-dish containing 50
70 healthy cowpea seeds (Ife Brown) exposed to microwave irradiation at 100 watts power level for 0, 2, 4, 6, 8
71 and 10 minutes. The experiment was conducted using Completely Randomized Design (CRD) replicated five
72 times. Mortality was recorded at 24, 48, 72 and 96 hours after treatments. Mortality data were corrected using
73 the method of Abbot (1925). LD₅₀ values were estimated by subjecting mortality data to the maximum
74 likelihood program of probit analysis (Robertson *et al.*, 2007) using SPSS software. Weevil Perforation Index
75 (WPI) was determined using the procedure of (Fatope *et al.*, 1995).

$$\text{Weevil Perforation Index} = \frac{\% \text{ of treated grains perforated} \times 100}{\% \text{ of control grains perforated} + \% \text{ of treated grains perforated}}$$

79

80

81 **Effect of irradiations on the viability of cowpea seeds**

82 **Germination Test** .This was carried out in the screen house using seedling Trays. Two seeds from each
83 treatments were randomly selected and planted in each hole and watered daily. The experimental design was
84 Completely Randomized Design (CRD) replicated ten times.

85 Data were collected on seedling emergence at 4, 5, 6 and 7 days after planting. Percentage emergence was
86 determined using the formular: $\frac{\text{Number of emerged seeds} \times 100}{\text{Number of seeds planted}}$

$$\text{Percentage emergence} = \frac{\text{Number of emerged seeds} \times 100}{\text{Number of seeds planted}}$$

88 **Proximate composition** : After three months of storage, irradiated and unirradiated cowpea seeds were
89 analyzed in triplicate for protein, moisture, ash content, crude fibre and carbohydrate using the official and
90 standard methods of analysis (AOAC, 1980).

91

92 3. RESULTS AND DISCUSSION

93
94 **Mortality test:** Results on the effect of microwave irradiations (100 watts) on the control of the *C. maculatus*
95 are presented in Table 1. The results showed that all the exposure periods 2, 4, 6, 8 and 10 minutes
96 reduced the population of *C. maculatus* 24 hours after exposure with insects exposed to 100 watts power
97 level for 8 minutes having the highest mortality level (24.05 ± 5.04) while control had the least value (0.00).
98 All the exposure periods significantly ($P < 0.05$) differed from control except insects exposed to 2 minutes and
99 4 minutes. There was no significant difference ($P > 0.05$) among *C. maculatus* exposed for 6, 8 and 10
100 minutes.

101 At 48 hours after exposure to microwave irradiation, the mortality level followed the same trend with *C.*
102 *maculatus* exposed for 8 minutes having a percentage mortality level of (43.89 ± 7.16) while control had the
103 least value (0.00 ± 0.00). However, insects exposed for 2 and 4 minutes did not significantly ($P > 0.05$) differ
104 from control. Insect exposed for 6, 8 and 10 minutes did not differ from one another but significantly ($P < 0.05$)
105 differ from other exposure periods.

106 At 72 hours after exposure, *C. maculatus* exposed for 10 minutes had the highest mortality level ($67.54 \pm$
107 6.05) while control had the least value (0.00 ± 0.00). The results showed that all the exposure periods except
108 insects exposed for 2 minutes significantly ($P < 0.05$) differed from control. However, there was no significant
109 difference ($P > 0.05$) between insects exposed for 6, 8 and 10 minutes.

110 At 96 hours after exposure, the percentage mortality level was in the following order: 10 minutes exposure
111 (74.41 ± 3.53) > 8 minutes (77.26 ± 4.05) > 6 minutes (55.00 ± 5.49) > 4 minutes (33.09 ± 2.00) > 2 minutes
112 (16.55 ± 2.21) > control (0.00 ± 0.00).

113 Results showed that mortality of *C. maculatus* increased with increase in the time of exposure to microwave
114 irradiation. The mortality of insects could be due heating up of water in insects thereby causing death by
115 cellular disruption (Phillips and Throne, 2010). Similar observation was made by Phillips *et al.* (2003), who
116 reported that application of high energy microwaves in the flowing grain of a pilot scale trial

117 Table 1: Effect of microwave irradiation (100 watts) on the mortality of *C. maculatus*

Treatment	Mortality			
	24 hrs	48 hrs	72 hrs	96 hrs
Control (0 Minutes)	0.00 ^c ± 0.00	0.00 ^c ± 0.00	0.00 ^c ± 0.00	0.00 ^e ± 0.00
2 Minutes exposure	4.22 ^c ± 2.59	4.22 ^c ± 2.59	14.09 ^{bc} ± 7.46	16.55 ^d ± 2.21
4 Minutes exposure	8.17 ^{bc} ± 6.48	15.83 ^{bc} ± 4.38	27.02 ^b ± 5.62	33.09 ^c ± 2.00
6 Minutes exposure	19.89 ^{ab} ± 3.79	31.94 ^{ab} ± 6.09	54.41 ^a ± 4.41	55.00 ^b ± 5.49
8 Minutes exposure	24.05 ^a ± 5.04	43.89 ^a ± 7.16	66.98 ^a ± 3.99	77.26 ^a ± 4.05
10 Minutes exposure	22.11 ^{ab} ± 3.10	32.50 ^{ab} ± 7.12	67.54 ^a ± 6.05	74.41 ^a ± 3.53

118 Means with the same letters within the same column are not significantly different ($P \geq 0.05$)

119 was effective in killing insect pests without any negative effect on the quality of the grains. Vidavambal *et al.*
120 (2010) who worked on disinfestations of stored corn using microwave energy reported that microwave
121 irradiation was effective against 3 stored grain insects: *Sitophilus zeamais*, *Tribolium castaneum* and *Plodia*
122 *interpunctella*. They reported that microwave irradiation with good penetrability can kill pests existing inside or
123 outside grain kernels.

124 **Lethal Time (LT₅₀)**. This was determined using the maximum likelihood of probit analysis and the results are
125 as presented in Table 2. The results showed that mortality increased with time after exposure to microwave
126 irradiation. Ninety six (96) hours after exposure had the least LT₅₀ value of 5.2 minutes when compared with
127 other exposure periods. The LT₅₀ value is in the following order: 96 hours after exposure (5.2 minutes) < 72
128 hours < (5.8 minutes) < 48 hours (12.2 minutes) < 24 hours (29.1 minutes).

129 The result implies that exposure of *C. maculatus* to microwave irradiation (100 power level) for 29.1 killed
130 50% of the pest population within 24 hours. Exposure for 12.2 minutes killed 50% of pest population within
131 48 hours, exposure for 5.8 killed 50% of pest population within 72 hours while exposure for 5.2 minutes killed
132 50% of pest population within 96 hours. This corroborates the report of Zhao *et al.*, (2007) who worked on a

133 thermal lethal model of rice weevils subjected to microwave irradiation and reported that lower power with
134 longer treatment time is more effective at killing insect pests.

135 Table 2: LT₅₀ values of microwave irradiations (100 watts)

Time (hours)	LT ₅₀
24	29.1± 5.6
48	12.2± 0.9
72	5.8± 0.5
96	5.2± 0.4

136

137 **Damage Assessment.** The effect of microwave irradiation on the percentage perforation of cowpea seeds,
138 number of seeds perforated and Weevil Perforation Index (WPI) is shown in Table 3. Results showed that
139 there were significant differences ($P \leq 0.05$) among the exposure periods. Control had the highest percentage
140 seed perforation value (81.20±2.42) while seeds exposed to microwave irradiation (100 watts) for 10
141 minutes had the least value (36.80±2.42). Similarly, control had the highest number of seeds perforated
142 (40.60±1.21) while seeds exposed to microwave irradiation for 10 minutes had the least value (18.40±1.21).

143 The least Weevil Perforation Index (45.3) was recorded in cowpea seeds exposed to microwave irradiation
144 for 10 minutes. Exposure to microwave irradiation for 2 minutes had had WPI (68.5), exposure for 4 minutes
145 had WPI (55.7), exposure for 6 minutes had WPI (55.2) while exposure for 6 minutes had WPI (51.7).

146 Results on the assessment of damage to cowpea seeds exposed to microwave irradiation (100 watts power
147 level) shows that the different exposure periods gave varied degree of protection when compared with
148 control. The different exposure periods did not effectively protect the cowpea seeds after 3 months of storage
149 as seen in the Weevil Perforation Index values which are above 50. However, cowpea seeds exposed to
150 microwave irradiation for 10 minutes which have a Weevil Perforation Index of (45.3) offered better

151 protection against *C. maculatus* when compared with other exposure periods. The reduction in the
152 percentage perforation of cowpea seeds exposed for 10 minutes could be due to reduction in moisture
153 content and the hardening of seed coat as a result of longer time of exposure to microwave radiation which
154 makes it difficult to perforate the seeds.

155 **Germination Test.** The results of the effect of microwave irradiation on the seed viability are as shown in
156 Table 4. Emergence count was taken at 4, 5, 6 and 7 days after planting. At 4 days after planting, cowpea
157 seeds exposure for 4 minutes had the highest value (35.00 ± 10.67). However, there was no significant
158 difference ($P \leq 0.05$) among all the exposure periods. At 5 days after planting, cowpea seeds exposed for 2
159 minutes had the highest value (55.00 ± 11.67) while cowpea seeds exposed for 10 minutes had the least
160 value (10.00 ± 6.67). All the exposure periods significantly ($P \leq 0.05$) differed from cowpea seeds exposed for
161 10 minutes but did not differ significantly ($P \geq 0.05$) from one another.

162 At 6 days after planting, cowpea seeds exposed for 2 and 4 minutes had the highest values (65.00) while
163 those exposed for 10 minutes had the least value (25.00 ± 11.18). Though there was no significant
164 difference ($P \geq 0.05$) among all the exposure periods.

165 At 7 days after planting, their performances were in the following order: 2 minutes exposure (70.00 ± 11.06)
166 > 4 minutes (65.00 ± 13.02) > 6 minutes (60.00 ± 12.47) = 8 minutes (60.00 ± 12.47) > control ($40.00 \pm$
167 14.53) > 10 minutes (30.00 ± 11.06). Though, there was no significant difference.

168 The results showed that the germination and emergence of cowpea seeds exposed to microwave irradiation
169 decreased with increase in exposure time. However, there was no significant difference ($P \geq 0.05$) among all
170 the exposure periods. Similarly observation was made by Vadivambal *et al.*, (2010) who reported that
171 germination of corn exposed to microwave irradiation decreased as power level and exposure time
172 increased. Campana *et al.*, (1993) who studied the physical, chemical and baking properties of wheat dried
173 with microwave energy concluded that germination capacity was decreased by microwave energy. The
174 decrease in germination capacity was related to the final temperature and the moisture contents of the grain.

175

176 Table 3: Damage assessment of cowpea seeds exposed to microwave irradiation (100 watts)

Treatments	Perforated seeds	Unperforated seed	% seed Perforation	WPI
Control	40.60 ^a ±1.21	9.40 ^c ±1.21	81.20 ^a ±2.42	-
2 minutes	27.80 ^b ±1.83	22.20 ^b ±1.83	55.60 ^b ±3.66	68.5
4 minutes	22.60 ^c ±1.81	27.40 ^a ±1.81	45.20 ^c ±3.61	55.7
6 minutes	22.40 ^c ±1.08	27.60 ^a ±1.08	44.80 ^c ±2.15	55.2
8 minutes	21.00 ^c ±0.71	29.00 ^a ±0.71	42.00 ^c ±1.41	51.7
10 minutes	18.40 ^c ±1.21	31.60 ^a ±1.21	36.80 ^c ±2.42	45.3

177 Means with the same letters within the same column are not significantly different ($P \geq 0.05$)

178

179 Table 4: Effect of microwave irradiation (100 watts) on the percentage grmination of cowpea
180 seeds

Treatments	4 DAP	5 DAP	6 DAP	7 DAP
Control	20.00 ^a ± 8.17	20.00 ^b ± 18.17	40.00 ^a ± 14.53	40.00 ^a ± 14.53
2 Minutes exposure	25.00 ^a ± 11.18	55.00 ^a ± 11.67	65.00 ^a ± 10.67	70.00 ^a ± 11.06
4 Minutes exposure	35.00 ^a ± 10.67	50.00 ^{ab} ± 10.54	65.00 ^a ± 13.02	65.00 ^a ± 13.02
6 Minutes exposure	15.00 ^a ± 7.64	40.00 ^{ab} ± 12.47	55.00 ^a ± 11.67	60.00 ^a ± 12.47

8 Minutes exposure	10.00 ^a ± 6.67	25.00 ^{ab} ± 8.33	60.00 ^a ± 12.47	60.00 ^a ± 12.47
10 Minutes exposure	10.00 ^a ± 6.67	10.00 ^c ± 6.67	25.00 ^a ± 11.18	30.00 ^a ± 11.06

181 DAT – Days after planting. Means with the same letters within the same column are not
182 significantly different ($P \geq 0.05$)

183 **Proximate composition.** The results on the effect of microwave irradiation (100 watts) on the proximate
184 composition of cowpea seeds are presented in Table 45. The proximate compositions determined are
185 protein, fat, fibre, ash, moisture and carbohydrates. The results showed that control had the highest protein
186 value (24.07 ± 0.34) while cowpea seeds exposed for 10 minutes had the least value (21.00 ± 0.21). Control
187 significantly ($P \leq 0.05$) differed from other treatments. There was no significant difference ($P \geq 0.05$) between
188 cowpea seeds exposed for 4 and 6 minutes. Similarly, there was no significant difference between cowpea
189 seeds exposed for 8 and 10 minutes. The range of protein content is between 21.00 and 24.07. The
190 reduction in protein content noticed in this experiment could be as a result of denaturing of protein by
191 microwave irradiation that involves heat. The protein range between 21.00 and 24.07% observed in this
192 experiment is similarly to the report of Onwuliri and Obu, 2002. The results from their experiment on Lipids
193 and other Constituents of *V. unguiculata* and *Phaseolus vulgaris* grown in Northern Nigeria showed protein
194 content value between 20.5 and 31.7%. Adekola and Oluleye, (2007) who worked on influence of mutation
195 induction on the chemical composition of cowpea, *V. unguiculata* reported a protein content value between
196 16.04 and 31.06%. Similarly, Appiah *et al.*, 2011 who researched on Physico-chemical and functional
197 properties of bean flours of three cowpea (*V. unguiculata*) varieties in Ghana reported a protein content
198 between 26.53 and 29.00%.

199 The result on the effect of microwave irradiation on the fat content of cowpea seeds showed that control
200 (unexposed) seeds had the highest value of 3.07 ± 0.29 while cowpea seeds exposed for 2 minutes had the
201 least value 2.20 ± 0.12 . Control significantly ($P \leq 0.05$) differed from other exposure periods. However, there is
202 no significant difference among other exposure periods. The significant difference observed is an indication

203 that the difference was induced by microwave irradiation. The reduction in crude fat content is healthy as
204 most fatty foods are associated with high cholesterol that are injurious to human health. Alector and
205 Aladetimi, (1989) who worked on compositional evaluation of some cowpea varieties and some under
206 utilized edible legumes in Nigeria reported an average crude fat content of 5.9%. Adekola and Oluleye,
207 (2007) reported a crude fat content of 2.40 – 4.33%, Appiah, *et al.*, (2011) reported a crude fat content of
208 2.50 – 3.99% while Onwuliri and Obu, (2002) observed a crude fat content of 1.14 – 3.03%.

209 Cowpea seeds exposed for 2 minutes had the highest fibre content (2.23 ± 0.03) while the seeds exposed
210 for 10 minutes had the least value (1.73 ± 0.03). There was no significant difference ($P \geq 0.05$) among
211 cowpea seeds exposed for 2, 4 and 6 minutes but they significantly differ from others. Similarly, there was no
212 significant difference among seeds exposed for 8, 10 minutes and control. Adekola and Oluleye, (2007)
213 reported a crude fibre content of 1.03 – 3.95% while Onwuliri and Obu, (2002) reported a crude fibre content
214 of 1.7 – 4.5%. High crude fibre content could be useful in providing bulk to foods to aid digestibility and to
215 minimize constipation (Appiah *et al.*, 2011).

216 Microwave irradiation (100 watts) did not significantly affect the ash content of cowpea seeds. However,
217 control had the highest value (3.53 ± 0.27) while cowpea seeds exposed for 10 minutes had the least value
218 (2.93 ± 0.09). Appiah *et al.*, (2011) reported ash content of 2.95 – 3.22% while Henshaw (2008) who worked
219 on the Varietal Differences in Physical, Chemical and Proximate composition of cowpea (*V. unguiculata*)
220 reported ash content of 3 – 4%. High ash content could be important source of minerals for consumers
221 (Brown, 1991)

222 Moisture content of cowpea seeds was significantly ($P \leq 0.05$) affected by microwave irradiation. Cowpea
223 seeds exposed for 2 minutes had the highest value (10.67 ± 0.24) while the ones exposed for 10 minutes
224 had the least (8.20 ± 0.20). There was no significant difference among all the exposure periods except
225 cowpea seeds exposed for 10 minutes. Reduction in moisture content could be as a result of heat generated
226 by microwave irradiation. Low moisture content will enhance storability of cowpea seeds and could minimize
227 seed perforation by *C. maculatus* owing to hardness of seed coat.

Carbohydrate content of cowpea seeds was significantly affected by microwave irradiation. Cowpea seeds exposed for 10 minutes had the highest value (63.80 ± 0.15) while the control had the least value (56.97 ± 0.90). Cowpea seeds exposed for 10 minutes significantly differed from other exposure periods. There was no significant difference among cowpea seeds exposed for 2, 4 and 6 minutes. Appiah, *et al.*, 2011 reported carbohydrate content of 50.22 – 53.98%. High carbohydrate and ash contents indicate that cowpea could be important sources of minerals and energy for consumers (Brown, 1991).

Table 5. Effect of microwave irradiation (100 watts) on the proximate composition of cowpea seeds

Treatments	Protein	Fat	Fibre	Ash	Moisture	Carbohydrate
Control	$22.97^b \pm 0.20$	$2.20^b \pm 0.12$	$2.23^a \pm 0.03$	3.27 ± 0.03	$10.67^a \pm 0.24$	$58.67^c \pm 0.24$
2 Min. exposure	$23.00^b \pm 0.15$	$2.53^b \pm 0.07$	$2.13^{ab} \pm 0.12$	3.10 ± 0.06	$10.10^a \pm 0.06$	$59.13^c \pm 0.27$
4 Min. exposure	$22.73^b \pm 0.18$	$2.57^b \pm 0.03$	$2.07^{ab} \pm 0.09$	3.07 ± 0.03	$9.53^{ab} \pm 0.54$	$60.03^c \pm 0.49$
6 Min. exposure	$21.20^c \pm 0.12$	$2.43^b \pm 0.03$	$1.83^{bc} \pm 0.03$	3.10 ± 0.12	$9.33^{ab} \pm 0.41$	$62.10^b \pm 0.26$
8 Min. exposure	$21.00^c \pm 0.21$	$2.33^b \pm 0.07$	$1.73^c \pm 0.03$	2.93 ± 0.09	$8.20^b \pm 0.20$	$63.80^a \pm 0.15$
10 Min. exposure	$24.07^a \pm 0.34$	$3.07^a \pm 0.29$	$1.87^{bc} \pm 0.09$	3.53 ± 0.27	$10.50^a \pm 0.45$	$56.97^d \pm 0.90$

236

237 REFERENCES

- 238 Abbot, W.S. 1925. A method of computing the effectiveness of an insecticide. *Journal of*
239 *Economic Entomology*, 18: 265 – 267.
240
241 Adeduntan, S.A. and Ofuya, T.I. 1998. Evaluation of seeds of selected varieties of cowpea,
242 *Vigna unguiculata* (L.) Walp. for susceptibility to *Callosobruchus maculatus* (F.) (Coleoptera :
243 Bruchidae). *Applied Tropical Agriculture*, 3: 45 – 51.
244
245 Adekola, F.O. and Oluleye, F. 2007. Influence of mutation induction on the chemical
246 composition of cowpea, *Vigna unguiculata* (L.) Walp. *African journal of Biotechnology*, Vol.6
247 (18): 2143 – 2146.
248

249 Alektor, V.A. and Aladetimi, O.O. 1989. Compositional evaluation of some cowpea varieties
250 and some under utilized edible legumes in Nigeria. *Nahrung*, 33(10): 999 – 1007.
251

252 Akinkurolere, R.O., Adedire, C.O. and Odeyemi, O.O. 2006. Laboratory evaluation of the
253 toxic properties of forest anchomanes, *Anchomanes difformis* against pulse beetle,
254 *Callosobruchus maculatus* (Coleoptera: Bruchidae). *Insect Science*, 13: 25 – 29.
255

256 Allotey, J., Sefa-Dedeh, S., Osei, A.K. and Collison, E.K. 2012. Comparative study of the
257 effects of steam and solar heat treated cowpea seeds on the development and control of
258 *Callosobruchus maculatus* (F.) (Coleoptera : Bruchidae). *African Journal of Food,*
259 *Agriculture, Nutrition and Development*, Vol.12, pp. 6065 – 6078.
260

261 Association of Official Analytical Chemists (AOAC) 1980. Official Methods of Analysis, 17th
262 ed. Association of Official Agricultural Chemists, Washington, D.C. Official Methods of
263 Analysis 14, pp. 213.
264

265 Appiah, F., Asibuo, J.Y. and Kumah, P. 2011. Physioco-chemical and functional properties of
266 beans flours of three cowpea (*Vigna unguiculata* (L.) Walp) varieties in Ghana. *African*
267 *Journal of food Sci.* Vol. 5(2): 100 – 104.
268

269 Begum, S., Mannan, A. and Begum, A. 2009. Effect of sunning on different pulse seed
270 infested by the pulse beetle, *Callosobruchus chinensis* (L.). *Bangladesh Journal of Zoology*,
271 19: 262 – 265.
272

273 Brown, K.H. 1991. The importance of Dietary Quality versus Quantity for weaning in the
274 developed countries: A framework for Discussion. *Food Nutri. Bull.*, 13(2): 86 – 93.
275

276 Campana, L.E., Sempe, M.E. and Filueria, R.R. 1993. Physical, chemical and baking
277 properties of wheat dried with microwave energy. *Cereal Chem.*, 70(6): 760 – 762.
278

279 Fatope, M.O., Mann, A. and Takeda, Y. 1995. Cowpea weevil bioassay: A simple pre-screen
280 for plants with grain protectant effects. *International Journal of Pest Management*, 41: 44 –
281 86.
282

283 Follett, P.A., Yang, M.H., Lu, K.H. and Chen, T.W. 2007. Irradiation for postharvest control of
284 quarantine insects. *Formosan Entomol.* 27 : 1 – 5.
285

286 Gasemzadeh, S., Pourmiiza, A.S., Safarligadeh, M.S. and Maroufpoor, M. 2010. Effect of
287 microwave radiation and cold storage of *Tribolium castaneum* Herbst (Coleoptera :
288 Tenebrionidae) and *Sitophilus oryzae* L. (Coleoptera : Curculionidae). *Journal of Plant*
289 *Protection Research*, 50 (2): 140 – 145.
290

291 Henshaw, F.O. (2008). Varietal differences in physical characteristics and proximate
292 composition of cowpea (*Vigna unguiculata*). *World J. Agric. Sci.* 4(3): 302 – 306.
293

294 IITA (International Institute of Tropical Agriculture), 2003. Crop and Farming systems.
295 Retrieved from : <http://www.iita.org/crop/cowpea.htm>.
296

297 International Institute of Tropical Agriculture (IITA), 1982. Cowpea production training
298 manual. IITA Manual series no.11: 190 pp.
299

300 Ogunwolu, O. And Odunlami, A.T. 1996. Suppression of seed bruchid, *Callosobruchus*
301 *maculatus* development and damage on cowpea, *Vigna unguiculata* with *Zanthoxylum*

302 *zanthoxyloides* (Lam.) Western (Rutaceae) root bark powder. Crop Protection, 15: 603 –
 303 607.
 304
 305 Onwuliri, V.A. and Obu, J.A. 2002. Lipids and other constituents of *Vigna unguiculata* and
 306 *Phaseolus vulgaris* grown in Northern Nigeria. Food chemistry, 78(1): 1 – 7.
 307
 308 Phillips, R.D., McWatters, K.H., Chinannan, M.S., Hung, Y., Beuchat, L.R., Sefa-Dedeh, S.,
 309 Saki-Dawson, E., Ngoddy, P., Nnayelugo, D., Enwere, J., Komey, N.S., Liu, K., Mensa-
 310 Wilmot, Y., Nnanna, I., Okeke, C., Prinyawiwatkul, W. and Saalia, F.K. 2003. Utilization of
 311 cowpea for human food. Field Crops Research, 82: 193 – 213.
 312
 313 Phillips, T.W. and Throne, J.E. 2010. Biorational Approaches to Managing Stored Product
 314 Insect insects. Annu. Rev. Entomol. 55: 375 – 397.
 315
 316 Robertson, J.L., Rusell, R.M., Preisler, H.K. and Savin, E. 2007. Bioassays with Arthropods,
 317 2nd Rev. Edn., CRC Press, Boca Ratone, FL.
 318
 319 Sanginga, N., Dashiell, K.E., Diels, J., Vanlauwe, B., Lyasse, O., Carsky, R.J., Tarawali, S.,
 320 Asafo-Adjei, B., Menkir, A., Schulz, S., Singh, B.B., Chikoye, D., Keatinge, D. and Ortiz, R.
 321 2003. Sustainable resource management coupled to resilient germplasm to provide new
 322 intensive cereal-grain-legume-livestock systems in the dry savanna. Agric. Ecosystem
 323 Environ, 100: 305 – 314.
 324
 325 Vadivambal, R., Deji, O.F., Jayas, D.S. and White, N.D.G. 2010. Disinfestation of stored
 326 corn using microwave energy. *Agricultural and Biology Journal of North America*, 1(1): 18 –
 327 26.
 328
 329 Zhao, S., Qui ch., Xiong sh and Cheng, X. 2007. A thermal lethal model of rice weevils subjected to
 330 microwave irradiation. *Journal of Stored Products Research*, 43: 430 - 434.