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Phytochemical composition and insecticidal properties of mechanicaly extracted castor, seed oil against cowpea seed bruchid (*Callosobruchus maculatus* Fabricius) infesting bambara groundnut

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ABSTRACT

The phytochemical analysis of mechanically extracted castor (*Ricinus communis* L.) seed oil (CSO) was carried out using gas chromatography- mass spectrometry (GCMS). A total of seven compounds {oleic acid (54.97%), stearic acid (16.53%), palmitic (10.35%), ricinoleic (9.61%), squalene (3.17%), palmitin, 1, 3-di- (3%) and octadecanoic acid (2.37%)} were identified from the spectra. The ability of CSO to protect bambara groundnut seed against *Callosobruchus maculatus* Fabricius was also evaluated under laboratory conditions (26±2°C temperature and 75±5% relative humidity). Percentage repellency was concentration-depedendent, with 13.07% observed in the control being significantly ($p<0.05$) lower than percentage repellency observed in other treatments. Contact toxicity increased with exposure period. At 2 hours after treatment (HAT), mortality of *C. maculatus* was significantly higher ($p<0.05$) at 1.0 µl/ beetle than the control. When CSO was applied at 0.5 µl/ beetle, the LT_{50} value was 0.59 (0.25-0.83) h. Percentage mortality of *C. maculatus* in bambara groundnut treated with CSO increased with concentration. The LD_{50} against *C. maculatus* was 0.14 (0.05-0.22) µl per 50 grams seeds. Application of CSO at the rate of 0.7- 1.5 µl per 50 g bambara groundnut seed gave significantly ($p<0.05$) higher percentage oviposition inhibition rate than what were obtained in methanol-treated and untreated controls. Percentage seed damage (4.74%) observed in 1.5 µl/ 50 g was significantly ($p<0.05$) lower than 15.26 and 17.66 % observed in methanol-treated and untreated control respectively. The results obtained indicate that CSO could be used to control *Callosobruchus maculatus* in stored bambara groundnut.

Introduction

Apart from cowpea which is the major legume susceptible to infestation by *Callosobruchus maculatus*, bambara groundnut (*Vigna subterranea*) is another susceptible species (Haines, 1991; Mbata, 1992; Lale and Vidal, 2001). As a protein source, it is a legume that can effectively substitute cowpea considering the rate at which the demand for cowpea is increasing by the day. Bambara groundnut is important for smallholders and their households because the beans are an important source of food security, being nutritious and high in protein (Hillocks et al, 2012). It has the potentials to improve nutrition, food security, foster rural development and support sustainable land care (National Research Council, 2006). The crop is one of rural African's most popular grain legumes, ranking third in importance after groundnut (*Arachis hypogeal* L.) and cowpea (*Vigna unguiculata* (L.) Walpers) (Lale and Ajayi, 2001). Its potential has however been limited due to storage insect pest attack of which a major one is *C. maculatus*. Species of the genus *Callosobruchus* Pic (Coleoptera: Bruchidae) seriously damage legume seeds, especially in warm parts of the Old World from which it originates (Udayagiri and Wadhi, 1989; Singal and Pajni, 1990). Damage as high as 100% by *C. maculatus* is possible especially when legume seeds are left untreated over a period of time. The use of chemical is the most prominent method for controlling stored product pests and has traditionally been used to protect grain (Arthur 1996). However, some negative effects have been associated with the use of chemical such as ozone layer depletion, high costs of chemicals, resistance of pests to pesticides and harmful effects on human beings (Bell and Wilson 1995; WMO 1995; Gao et al. 2008). As a result of the problems that synthetic insecticides cause to the environment as well as to human health, there has been an up-surge of research on plant products for the control of insect pests (Islam et al., 2009; Castillo-Sanchez et al., 2010; Saroukolai et al., 2010; Babarinde et al., 2013).

Castor oil plant (*Ricinus communis* L.) is a species of flowering plant in the spurge family Euporbiaceae. It belongs to a monotypic genus *Ricinus*, and possess insecticidal properties which control insect pests such as *C. maculatus* and

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Acanthoscelides obtectus (Salas and Hernandez, 1985). Babarinde et al. (2008; 2011) reported its insecticidal properties against *Nasutitermes* species and rust red flour beetle, *Tribolium castaneum*. It has also been reported to significantly reduce weight loss in wood pieces exposed to termites (Sharma et al., 1990). Leave extract of *R. communis* has been reported to be effective against *Culex pipiens, Aedes caspius, Culiseta longiareolata* and *Anopheles maculipennis* (Diptera: Culicidae) (Aouinty et al., 2006; Mandal, 2010). Okonkwo and Okoye (1992) reported the insecticidal activity of dried ground leaves of *R. communis* against *C. maculatus* (Coleoptera: Bruchidae). Castor oil has insecticidal activity against *Zabrotes subfasciatus* (Coleoptera: Bruchidae) (Mushobozy et al., 2009). Apart from the oil found in the seed, other components of the seed include ricin (Achaya et al., 1964; Darby et al., 2001), the protein allergens Ric c1 and Ric c3 (Bashir et al., 1998; Pantoja-Uceda et al., 2003) and ricinine (Bashir et al., 1998; Yudalshev, 2001). Ricinine found in the seeds and leaf of *R. communis* is effective in the control of *Myzus persicae* (Homoptera: Aphididae) (Olaifa et al., 1991) and *Attasexdens rubropilosa* (Hymenoptera: Formicidae) (Bigi et al., 2004).

Several authors have reported the use of organic solvent in extraction of *R. communis* (Upasani et al., 2003, Ramos-López et al., 2010, Babarinde et al., 2011; Ramos-López et al., 2012). The use of hydraulic press to extract CSO is necessitated by the search for eco-friendly toxic oil from ricinus seed such that the resulting non-poisonous cake can be incorporated into animal feed and/or organic manure. This work has its merit in the fact that the extraction method does not use organic solvent which can reduce costs and the press used for the extraction can be locally fabricated by local farmers. As well, *R. communis* is available in developing Asian and African countries and some parts of the developed world. Hence local farmers can adopt the product with less cost and reduced ecological risks. This study aims at evaluating the potential of mechanically extracted CSO using manually operated hydraulic press as postharvest protectant of bambara groundnut seeds against *C. maculatus*. The phytochemical constituents of the CSO were also evaluated using chromatographic procedure.

Materials and Methods

Research site

The research was carried out in the Department of Crop and Environmental Protection (CEP) Laboratory, Ladoke Akintola University of Technology (LAUTECH), Ogbomoso, Nigeria.

Bambara groundnut source and insect culture

Un-infested bambara groundnut seed obtained from Oja Oba Market, Ilorin, Nigeria was used to culture *C. maculatus* in three 1 litre capacity plastic jars as described by Babarinde and Ewete (2008). The culture was set up in a wooden shelf in the CEP Laboratory under ambient temperature of 26±2°C and relative humility of 75±5%. Adults were removed from the culture after oviposition to synchronize adult emergence needed for the laboratory experiment.

Extraction of CSO

The testa of *R. communis* seeds obtained from a local supplier in Ogbomoso, Nigeria were removed manually, 500 g of the de-husked seeds were grinded with a manually operated grinder (Corona®, a product of Landers Manufacturing Company, Medellin, Colombia) and the oil extraction was done using manually operated hydraulic screw press according to the method described by Babarinde et al. (2011). The CSO obtained was kept until use in a glass jar at room temperature.

Gas chromatography/mass spectrometry

Half millimitre of castor seed oil was resolved in 200 µl GC grade hexane for about 20 min (Omoleye and Vidal, 2007). Thereafter, the oil was injected into a GC-MS machine (GCMS-QP2010 Plus®, a product of Shimadzu, Kyoto, Japan), equipped with an AOC-20i auto sampler and a split injector (split ratio 1:50), The column used was Rtx-5MS (a product of Restok, USA) (30m × 0.25mm internal diameter × 0.25 µl film thickness) coated with 5% diphenyl 95% dimenthylpolysiloxane packing materials. Helium was used as the carrier gas at 50.1 kpa inlet pressure and 36.2cm/s linear velocity and a purge flow rate of 3ml/min and column flow rate 0.99 ml/min. oven temperature started with 40oC, for 5 min and ramp of 7ºC /min up to 90ºC held for 5 min and subsequent increase to 115ºC with a 4ºC/min heating ramp at 280ºC for 20 min. Injection temperature and volume were 220ºC and 1.0 µl respectively. The MS operating conditions were: ionization with an ion trap detector in full scan mode under electron impact ionization (EL) at 70eV, ion source temperature 180ºC; interface temperature 250ºC, scan range, 38-650 m/z.

Identification of different constituents of castor oil

The identification of the components was based on comparison of the relative Kovets retention index (RI) using a hydrocarbon homologue which was calculated according to Van Den Dool and Kretz (1963). The mass spectra of peaks obtained were compared with those of authentic standards from NIST/MST/EPA (National Institute of Standard and Technology, Gaithersbarz, MD, USA) (190,825 spectra; 163,198 unique compound; 163,195 chemical structures, 2005 Edition) software database and mass spectra from the literature (Adams, 2001). The relative concentration of the components (% composition) were obtained by peak areas (Rtx-5MS column) normalization without applying any correction factor as presented in total icon chromatogram (TIC) peak report.

Bioassays of insect

Repellency test

The method used for testing repellency of *R. communis* extract against *C. maculatus* adults was based on the area preference test described by (McDonald *et al*. 1970; Babarinde et al., 2013) with some modifications. The test arena consisted of 9 cm whatman No. 1 filter paper cut in half. Four dosages of the CSO were prepared by dissolving 0.25, 0.5, 0.75 and 1.0 ml of the CSO in 1.0 ml methanol. Each dosage was applied to a half paper disc as uniformly as possible by means of Hamilton syringe (Sigma®, model 705 N, a product of Sigma Chemical Company, St Louis, USA); the other half filter paper disc was left untreated. A control experiment was also set up with one paper half treated with 1.0 ml absolute methanol and the other half left untreated. Ten adults of *C. maculatus* were released at the center of each of the repellency chamber and then covered. Each treatment and control was repeated three times. The number of insects present in the untreated (Nc) and treated disc (Nt) was recorded at 24 hours after treatment (Babarinde and Adeyemo, 2010). The experiment was set up in a completely randomized design.

Percentage repellency (PR) values were computed as follows:

$$PR= \{(Nc- Nt)/ (Nc + Nt)\} \times 100$$

Contact toxicity test

Three dosages (0.5, 0.75, and 1.0 ml) of CSO serially diluted in 1.0 ml methanol were separately applied on the tergum of 10 teneral adult bruchids by Hamilton syringe at the rate of 0.25 µl per bruchid. The control was treated with 0.25 µl methanol. The ten treated adult bruchids were kept in a 9 cm diameter Petri dish in four replicates, Data on adult mortality were taken at 0.5, 1 and 2 hours after treatment (HAT).

Adult mortality, oviposition and seed damage

Fifty grams of clean un-infested bambara groundnut seeds were weighed using top loaded weighing machine (Scout ™ Pro – 400g , product of Ohaus® , USA) into 150 ml glass jars covered with perforated lids to allow respiration of the insects and prevent their escape. Four dosages (0.25, 0.75, 1.00 and 1.50 µl) of CSO per 50 g bambara groundnut seed was used for the bioassay. Each dosage of CSO was dissolved in 1.0 ml methanol and applied into each 150 ml capacity jar containing 50 g bambara groundnut seed with the aid of Hamilton syringe. Each jar was gently shaken manually to ensure uniform distribution of the CSO on bambara groundnut seeds. Two controls were set up which included seeds that were treated with 1.0 ml methanol and another without methanol. The solvent was allowed to evaporate before introducing 5 pairs (sex ratio 1:1) teneral *C. maculatus adults*. At 5 days after treatment (DAT), data were collected on the cumulative number of eggs laid on each treatment and % adult mortality. At 28 DAT, number of seed damaged due to emergence of F_1 *C. maculatus* was evaluated and expressed as the percentage of the original number of seeds. Percentgae Oviposition Iinhibition Rate(OIR) was calculated according to the formula

Percentage OIR= {(Oc- Ot)/ (Oc)} ×100

Where

Oc = Oviposition level in control seeds,

Ot = Oviposition level in treated seeds

Statistical analysis

Each of the experiment was laid out in a completely randomized design. Data were subjected to angular transformation and then Analysis of Variance (ANOVA) using SAS software package (SAS Institute, 2000). Tukey's HSD test at 5% probability level was used to separate the means where there was significant treatment effect. Probit analyses were done to determine LT50 an LD50 for toxicity bioassays using SPSS version 16 (SPSS, 2006).

Results

Yield and phytochemical composition of mechanically extracted CSO

The yield of the CSO obtained was 25% w/w. Oleic acid had the highest percentage composition (54.97%), followed in this order. Stearic acid (16.53%), Palmitic acid (10.35%), ricinoleic acid (9.61%), squalene (3.17%), palmitin, 1, 3-di-(3%) and octadecanoic acid (2.37%) (Table1).

Repellent activity of CSO against *C. maculatus*

Table 2 shows the repellent effect of CSO against *C. maculatus* tested. Percentage repellency was concentration-depedendent, with highest concentration (1 µl/30 cm2) having the highest level of repellency (100%) and repellency class V. Percentage repellency (13.07%) observed in the control was significantly (df=4, 10; F value = 9.14, p= 0.0022) lower than percentage repellency observed in other treatments.

Table 1. Phytochemical composition of mechanically extracted castor seed oil

S/N	Compound name[a]	Retention index[b]	Formula	% Composition[c]
1	Palmitic acid	1968	$C_{16}H_{32}O_2$	10.35
2	Oleic acid	2175	$C_{18}H_{34}O_2$	54.97
3	Stearic acid	2167	$C_{18}H_{36}O_2$	16.53
4	Palmitin,1,3-di-	4013	$C_{35}H_{68}O_5$	3.00
5	Ricinoleic acid	2337	$C_{18}H34O_3$	9.61
6	Octadecanoic acid	4395	$C_{39}H_{76}O_5$	2.37
7	Squalene	2914	$C_{30}H_{50}$	3.17

a.Compound names were identified by comparing MS with NIST (2005) using spectra software.

[b]. Kovats retention indices relative to n-alkanes on fused silica capillary column Rtx-5ms

c. Percentage peak area relative to total peak area obtained from TIC peak report.

Table 2. Effect of castor seed oil on repellency of *Callosobruchus maculatus*

Dosage of Extract (µl/30 cm^2)	Percentage repellency	Repellency Class
Methanol	13.00 (13.07) a	Class I
0.25	73.33 (59.20) b	Class III
0.50	73.33 (59.20) b	Class III
0.75	80.00 (64.20) b	Class IV
1.00	100.00 (90.00) b	Class V
ANOVA	df=4, 10; F value = 9.14, p = 0.0022	

Data in parenthesis are transformed data. Data are means of three replicates Means carrying the same letter along the column are not significantly different at 5% probability level using Tukey's HSD test.

Roman figures are repellency classes.

Repellency class 0: < 0.1%; Repellency class I: 0.1–20%

Repellency class II: 20.1–40%; Repellency class III: 40.1–60%.;

Repellency class IV: 60.1–80%; Repellency class V: 80.1–100%.

Contact toxicity of CSO against *C. maculatus*

Contact toxicity bioassay of CSO reveals that regardless of the concentration of the oil used, insect mortality increased with exposure period.

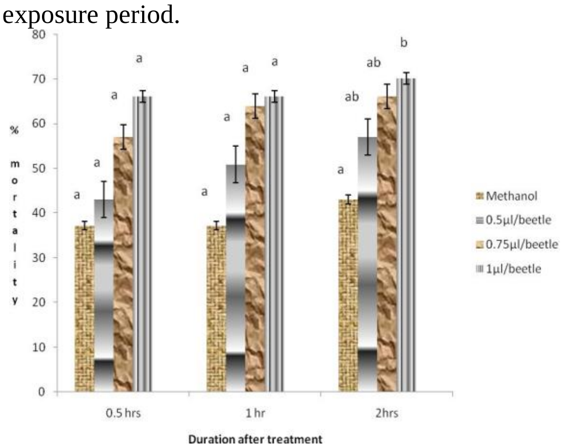

Figure 1. Contact toxicity of castor seed oil on *Callosobruchus maculatus.*

(Data are means of three replicates. Means carrying the same letter are not significantly different at 5% probability level using Tukey's HSD test)

At 0.5 HAT, the highest mortality (76.67%) of *C. maculatus* was observed at 1.0 µl/ beetle, though this was not significantly (df=3, 8; F value=3.23; P=0.082) different from other concentrations tested. However, at 2 HAT, mortality of *C. maculatus* was significantly higher (df=3, 8; F value=4.18; p=0.047) at 1.0µl/ beetle when compared with the control (Figure 1). LT_{50} of contact toxicity of CSO applied on *C. maculatus* adults decreased with increase in concentration. When CSO was applied at 0.5 µl/ beetle, the LT_{50} was 0.59 (0.25-0.83) h (Table 3).

Table 3. LT_{50} of contact toxicity of castor seed oil applied on tergum of *Callosobruchus maculatus* adults

Dosage	LT_{50} (h) Slope+ SE	Df	Chi square	P value
0.5 µl / beetle	0.59 (0.25-0.83) 3.13 ± 0.74	1	0.04	0.833
0.75 µl / beetle	0.09 (0.00-0.29) 9.52 ± 0.77	1	0.31	0.581
1.0 µl/ beetle	0.01 (-) 9.85 ± 0.08	1	0.49	0.486

95% lower and upper confidence intervals are shown in parenthesis.

Influence of CSO on percentage mortality, oviposition inhibition rate and bambara seed damage by *Callosobruchus maculatus*

Percentage mortality of *C. maculatus* in bambara groundnut treated with CSO increased with concentration. The highest mortality was observed when bambara groundnut was treated with 1 and 1.5 µl/50 g. These, however were not significantly different from other concentrations but were significantly higher (df=5, 18, F value=11.08, p<0.0001) than what was observed in the untreated control and methanol-treated seeds (Table 4). When CSO was applied on bambara groundnut seeds, the LD_{50} against *C. maculatus* was 0.14 (0.05-0.22) µl per 50 g seeds (Table 5). Oviposition Inhibition Rate (OIR) was also influenced by different concentrations of oil. Application of oil at the rate of 0.7-1.5 µl per 50 grams bambara groundnut seed gave percentage OIR that were significantly (df=5, 18 F value=15.68, p<0.0001) higher than what were obtained in the two controls (Table 4). Percentage seed damaged observed on the CSO treated seed of bambara groundnut was significantly (p<0.05) affected by the treatment. Seeds treated with the different concentrations of CSO were less damaged by the bruchid compared with the controls (Table 4).

Table 4. Influence of castor seed oil applied on bambara groundnut seed on percentage mortality, oviposition inhibition and seed damage due to infestation by *Callosobruchus maculatus*

Treatment (µl/ 50 g seed)	% mortality	% OIR	% seed damage
Control (methanol)	25.0 (26.20) c	0.00 (0.00) c	7.89(15.76)a
Untreated control	42.5 (40.60) bc	21.25 (23.30) bc	9.51(17.66) a
0.25	65.0 (54.00) ab	41.25 (39.83) ab	5.69(12.46) ab
0.75	77.5 (62.70) ab	62.25 (52.45) a	0.91(2.73) b
1.00	90.00 (74.15) a	69.50 (56.93) a	2.62(9.03) ab
1.50	92.5 (78.75) a	68.00 (55.68) a	1.49(4.74)b
ANOVA	df=5,18 F value=11.08, p<0.0001	df=5, 18 F value=15.68, p<0.0001	df=5, 18 F value=6.05, p = 0.0019

Data in parenthesis are transformed data. Data are means of four replicates. Means carrying the same letter along the column are not significantly different at 5% probability level using Tukey's HSD test.

Percentage seed damage (4.74%) observed in 1.5 µl/ 50 g was significantly (df = 5, 18; F value = 6.05, p = 0.0019) lesser than 15.26 and 17.66 % observed in methanol-treated and untreated control, respectively (Table 4).

Discussion

In this research, oleic acid (54.97%), stearic acid (16.53%), palmitic acid (10.35%), and ricinoleic acid (9.61%) were the major components observed in mechanically extracted CSO. Ramos-López et al. (2012) observed the following main components in hexane extract of the leaves of *R. communis*: linolenic acid (47.76%), linoleic acid (15.28%), palmitic acid (13.01%) and stearic acid (1.73%). Bigi et al. (2004) in their study observed principally palmitic acid (81.0%), stearic acid (6.6%), and pentadecanoic acid (6.4%) in the leaves of *R. communis*. The reason for the disparities observed in components and percentage compositions observed in the results was due to the disparity in parts of the plant studied. While Ramos-López et al. (2012) and Bigi et al. (2004) used the leaves for their experiment; seeds were used in this study. Other reasons for such differences observed may be due to weather, soil, geographic condition of growth, phenology of the plant and the variety of the species studied (Basta et al., 2007; Kpoviessi et al., 2012; Ramos-López et al., 2012).

Table 5. LD_{50} of castor seed oil applied on bambara groundnut seeds against *Callosobruchus maculatus*

LD_{50} (µl/50 g seed)	Slope+ SE	Df	Chi square	P value
0.14 (0.05-0.22)	12.3± 0.92	2	3.48	0.175

95% lower and upper confidence intervals are shown in parenthesis.

The potential of the leaf, fruit and bark of *R. communis* in the control of *Nasutitermes* species has previously been reported by Babarinde *et al*. (2008). The resultant mortality may either be by ingestion or contact (Calle et al., 1996). *R. communis* also has insectistatic properties (Rodríguez, 2005). Extracts of *R. communis* obtained with water, ethanol, methanol, dichloromethane, petroleum ether and hexane have biological activity against insects (Upasani et al., 2003, Rodríguez, 2005; Mushobozy et al., 2009). A very high percentage repellecy (100%) of *C. maculatus* by CSO at 24 HAT in the application rate of 1 µl/30 cm2 of essential oil implies that the oil is a good repellant and that repellency is concentration-dependent. Previous works by Babarinde et al. (2011) had reported the repellency of CSO oil against *T. castaneum*. The repellent property of CSO implies that it can prevent the non-resident population of *C. maculatus* from infesting stored bambara groundnut (Lale, and Alaga, 2001 and Babarinde and Adeyemo, 2010). *C. maculatus* was susceptible to contact application of CSO. Even at concentration as low as 0.5 µl/beetle, 70% mortality was observed at 2 HAT. Toxicity increased with exposure period with mortality as high as 83.33% observed at 2 HAT at 0.75 and 1 µl/beetle. This work confirms the findings of Salunke et al**.** (2005) who reported that toxicity of *C. chinensis* (L.) (Coleoptera: Bruchidae) exposed to flavonoids was exposure period-dependent. The toxicity of crude extract of *R. communis* against 2nd, 3rd and 4th instar larvae of *Anopheles arabiensis* and *Culex quinquefasciatus* had been reported by Elimam et al. (2009). According to the author, the LC50 values observed were 403.65, 445.66 and 498.88ppm against 2nd, 3rd and 4th instar larvae of larvae of *Anopheles arabiensis* and 1091.44, 1364.58 and 1445.44 ppm against

2nd, 3rd and 4th instar larvae of *Culex quinquefasciatus*, respectively. Although the mode of action of the oil was not investigated in this study, fatty acids have been reported as contact insecticides that enter the insect's body, where they block membrane permeability, thus leading to asphyxiation (Kuhne, 2008).

Percentage mortality of *C. maculatus* in bambara groundnut treated with CSO also increased with concentration. Toxicity of the oil in treated bambara groundnut against *C. maculatus* implies that *C. maculatus* picked lethal dose from the seeds as they moved about in the treated seeds. The fact that the percentage seed damage reduced with increasing concentration of CSO again substantiate the potential of this oil in bambara seed preservation at postharvest level. Several authors (Ofuya, 1986; Lale and Mustapha, 1999, Babarinde and Ewete, 2008; Sahaf and Moharramipour, 2008; Kiradoo and Srivastava, 2010) have reported the use of insecticidal plant products as protectants against *C. maculatus*. The significant increase in the percentage OIR of *C. maculatus* on bambara groundnut treated with CSO indicates that the oil has some oviposition inhibition properties. It could be that the oil reduced copulation of bruchids or that the number of eggs laid reduced due to mortality of the mated bruchids prior to egg laying. A high percentage OIR implies that the oil will drastically reduce population build-up in stored bambara groundnut. The result confirms the report of Adedire and Ajayi (1996), Koona and Dorn (2005), Babarinde and Ewete (2008), Kumar et al. (2009) and Abd El-Salam (2010), who reported that plant materials might be used for partial or full oviposition inhibition in *C. maculatus.* Crude extract of *R. communis* has also been reported to possess remarkable oviposition deterrent properties against *Anopheles arabiensis* and *Culex quinquefasciatus* (Elimam et al., 2009).

The phytochemical compounds (oleic acid, stearic acid, palmitic acid, ricinoleic acid, squalene, octadecanoic acid and palmitin, 1, 3-di-) identified in CSO were responsible for its insecticidal activities against *C. maculatus*. Adebowale and Adedire (2006) had reported the insecticidal properties of *Jathropha curcas* seed oil (containing palmitic acid, stearic acid and oleic acid) against *C. maculatus*. Hill and Schoonhoven (1981) reported oleic acid as toxicant against Mexican bean weevil, *Z. subfasciatus*, while Ramsewak et al. (2001) and Rahuman et al (2008) reported the insecticidal properties of oleic and linoleic acids against different species of mosquitoes.

Although there have been report of the insecticidal property of *R. communis* oil obtained from different methods against *C. maculatus*, this work is the first report of mechanically extracted CSO against *C. maculatus.* The research therefore substantiates the potential of incorporating organic pesticides of botanical origin such as CSO into integrated bruchid control. It is also recommended that CSO oil extracted by mechanical method, using hydraulic screw press, be assayed against other stored product insects; this will enable scientists to establish its spectrum of activity.

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