Waste Biomass Valor
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ORIGINAL PAPER

# Efficacy of Waste Biomass Based Tablet Formulation for Cockroach Control

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**Abstract** The current paper has elaborated the efficient utilization of house hold botanical waste like OP (orange peel), UTL (used tea leaves) and industrial waste i.e., KCP and JCP (non-edible oil seed cakes of Karanja and jatropha) for developing a herbal tablet formulation for cockroach control. The percentage mortality and KD50 values recorded with and without KCP and JCP were 25.9597, 100% (after 96 h) and 50.6697, 90% (After 96 h). Analysis with ATR-FTIR also confirmed the presence of presence of OP; KCP& JCP in tablet composition. SEM analysis generated the morphological details for the tablet containing active and other inert ingredients.

**Keywords** Jatropha cake powder (JCP) · Karanja cake powder (KCP) · Orange powder (OP) · Used tea leaves powder (UTL)

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## Introduction

Synthetic chemical insecticides have been considered as an important part of pest management for many years. Interest is however growing fast in discovering the possible role of plants and minerals as traditional protectants of stored products and as alternatives to the use of highly persistent synthetic chemicals with their attendant dangers and high cost. The use of natural products, which are cheap, effective, less toxic to mammals, easy to adopt and environmentally friendly have been investigated worldwide [1, 2]. Over 120 plants and plants products have been shown to have insecticidal or deterrent activity against stored product pests [3]. Currently, farmers in parts of Africa and Asia use some of these botanicals to protect their legumes from attack by bruchids, with varying degrees of success [4, 5]. However the number and quality of plants used by farmers is often limited by availability [5]. It was reported that powder peels of citrus fruits were effective in reducing the damage caused by *Callosobruchus maculatus* to cowpea seeds [6]. Also [7] reported that the crude extract of *Piper guineense* gave adequate protection to stored cowpea against *Callosobruchus maculatus*. Limonene, a monoterpene constituent in the extracts of citrus fruit peel was reported as a safe, natural pesticide for insect pests (Fig. 1a) [8]. The efficacy of orange peel has already been established [4].

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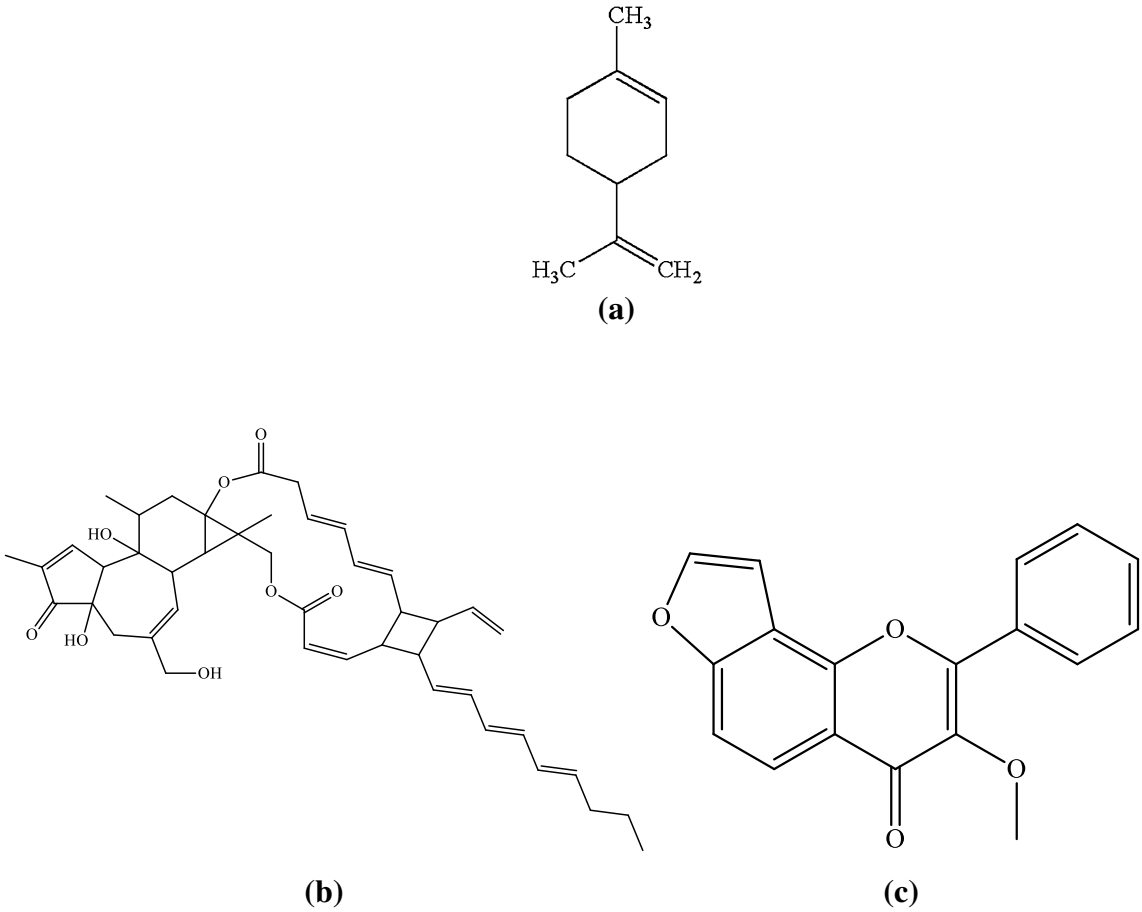



**Fig. 1** **a** Structure of Limonene, **b** structure of Jatropha (Phorbol esters), **c** structure of Karinjin (3-methoxyflavone)

Considering the extraction of oil from the non-edibleseeds, karanja (*Pongamia pinnata*) and jatropha (*Jatropha curcas*) have been selected as a major source of non-edible oil for production ofbiodiesel [9]. The technology of biodiesel production consumes only extracted vegetable oil from non-edible seeds and renders alarge amount of unutilized biomass as seed cake. Disposal of cake after expelling oil from seed has become a major concern in the past few years. Due to its toxic nature, the cake neither can be used for animal feeding nor can be used in agricultural farming.

The non-edible seeds of jatropha (*Jatropha curcas*) and karanja(*Pongamia glabra*) contain some toxic components, i.e., phorbolesters (Fig. 1b) in *Jatropha curcas* and karanjin (Fig. 1c) in *P. glabra*, which can be exploited to function as bio-pesticides [10].

Literature survey does give some information about the insecticidal activity of neem and karanja oil and their cakes in combination against mosquito vectors [11–13].

Household pests include the various insect species that invade human habitation causing damage to structures, eating human foods, acting as disease vectors and causing other threats. Cockroaches are one of the most commonly noted, unlikable household pests [14]. They have a widespread distribution with different species. eg. *Periplaneta americana, Blattella germanica, Blatta orientalis* etc. They produce odorous secretions that affect flavour of various food items. Disease producing organisms such as bacteria, protozoa and viruses have been found in their bodies. Different forms of gastroenteritis appear to be principal diseases transmitted by them. The disease causing organisms are carried on their legs and bodies and are deposited on food and utensils as they forage. Cockroach excrement and skin casts also contain a number of allergens to which people exhibit allergic responses such as skin rashes, asthma, etc [15].

In the present work, the knocking down and insecticidal activity of the tablet formulation containing bio-diesel by-product and orange peel powder based active ingredients individually and in combination has been compared with the efficacy of commercially available synthetic as well asherbal pesticide based product separately.

## Materials and Methods

Karanja, and jatropha cakes were collected from the Centre for Rural Development Technology, I.I.T, and Delhi. Orange peel and used tea leaves collected as household waste. Magnesium stearate was purchased from Merck, Mumbai, India.

### Preparation of Tablet

Botanical tablets (Fig. 2a) were prepared by mixing the botanical active ingredients and other components and compressing them into a solid mass using a Tablet Machine. They were kept in glass Petri dishes for some time at room temperature for drying and then used for Bio efficacy trials.

### Test Insect & Contact Toxicity Bioassay

The efficacy of the Tablets with and without the karanja and jatropha deoiled cake was evaluated against the American cockroach, *Periplaneta americana*. The cockroaches were collected from the fields of Delhi University, India, which are maintained as pesticide free zones by the university authorities with an average life expectancy of 600 days i.e. females-440 days and males-200–300 days. Cultures of *Periplaneta Americana* were maintained at laboratory conditions, 60–70% RH, 27 ± 1 °C and darkness i.e. 12:12 (L:D) h photoperiod in specially designed cages. The cages were made of coated polyacrylic material with dimensions and windows of muslin cloth on two sides for proper aeration and a slider door to keep and remove the cockroaches out of the cages.10 cockroaches were taken for each composition of tablet prepared and released into cages with 10 tablets as dose given to them. The experiment was carried in duplicates. Ten cockroaches were kept as control in cages with filter paper and moist bread provided to them as food with no other harbourage material in them. Observations were taken for knockdown and mortality characteristics for 96 h (Fig. 2b) [16].

Contact toxicity bioassay was performed by applying selected doses of the tablets (1 tablet for 1 cockroach) in the cages with the help of a micro applicator. 10 cockroaches were released in cages containing emulsion and mortality was observed after 24, 48, 72 and 96 h. Each assay for different doses of the emulsion was performed 3 times. A control set was also maintained [17].

### Analysis of Variance (ANOVA) and DMRT

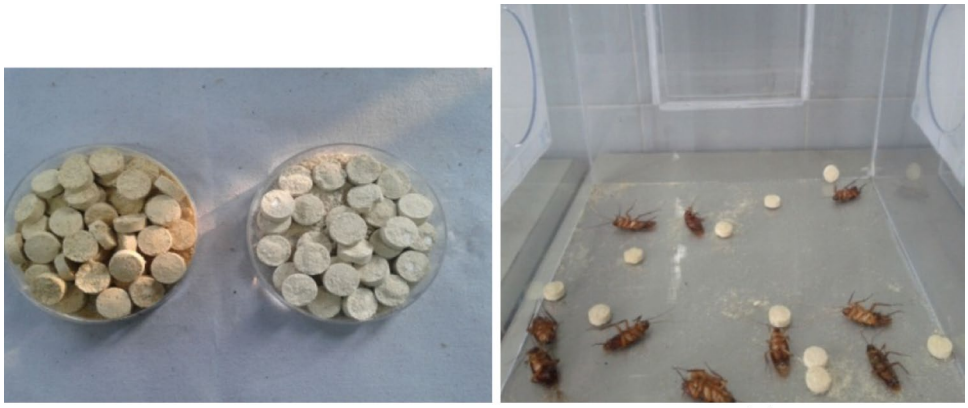
The results calculated here are means of three replicates. The standard deviation was calculated and reported as S.E. (Standard error) in the tables. The data was analysed by one-way analysis of variance (ANOVA) and significant effects were noted using SAS 9.4. along similar lines as in [18, 19]. Duncan's multiple range test (DMRT) 5% level was also employed to test for significant differences between treatments.

### ATR-FTIR Analysis of Tablet

Infrared (IR) spectra were recorded on a Bruker alpha ATR-FTIR spectrophotometer using the attenuated total reflectance (ATR) technique, and values are expressed as gmax $cm^{-1}$ [20].

### Scanning Electron Microscopy (SEM)

SEM photographs were taken with JSM 5600 scanning electron microscopy, (JEOL limited Tokyo, Japan) to analyze surface morphology of tablet containing orange peel powder, karanja cake powder and jatropha cake powder as a active ingredient [21].



(a) (b)

**Fig. 2** **a** Tablet formulation, **b** cockroach mortality

## Result and Discussion

The active component in tablet formulation is d-limonene, which is responsible for its insecticidal activity [18]. Confirmation of the active component in the tablet formulations prepared was done by using an ATR-FTIR technique. Limonene in general showed an infrared spectra in the following region of wave number; 2851 and C–H stretching spectra of limonene was found at 2900 $cm^{-1}$ (Fig. 3) [22]. Phorbol esters [23] and karinjin are the major constituents of jatropha and karanja cakesthat were responsible for their biopesticidal properties [24, 25]. Their presence in the tablet was confirmed by ATR-FTIR analysis.ATR-FTIR technique gives confirmation of no chemical reaction between active and inert ingredient in tablet formulation.

Scanning electron microscopy (SEM) analysis helped to study the surface modification of orange peel powder before and after mixing with other ingredients for preparing tablets [26] Fig. 4a, b. The surface of orange peel powder showed irregular distributed pores and the pores became smooth and uniform when mixed with other inert ingredients like binders and lubricant with orange peel powder [27].

Table 1 shows the percentage mortality data with time of tablets containing using orange peel powder (OP), used tea leaves powder (UTLP) and glucose. The mortality results were also compared with commercially available synthetic as well as botanical pesticide based products i.e. gel and tablets. Mortality values increased with time i.e. 10% in case of botanical (OP + UTLP + glucose) and 30% in case of market sample (synthetic and botanical) in 24 h. After 96 h values became similar i.e. 90% in both samples (botanical and market sample).Other compositions were also prepared by utilizing karanja cake powder (KCP) and jatropha cake powder (JCP) (Table 2) mixed with orange peel powder, used tea leaves powder and glucose along with magnesium stearate as a lubricant. In case of tablets containing KCP and JCP with combination of OP, UTLP and glucose, increase in the percentage mortality was 40–50% in 24 h as compared to market sample. After 96 h, Mortality rates reached to 100% as compared to market product i.e., synthetic (fipronil gel) as well as botanical (neemka paste) samples, where it was (90%).

Limonene [28] an active constituent of orange peel and also responsible for insecticidal activity [18], was used as an adsorbent in effluent treatment [29] process earlier. In the formulation described in the current paper, used tea leaves powder replaced the use of carbohydrate polymers like starch and cellulose. KCP and JCP containing karinjin and phorbol esters showed insecticidal activity against household as well as stored grain pest [10, 30], and the efficacy increased when combined with OP ,UTLP and glucose. Toxicity of phorbol ester against cockroaches was reported [31] but the presence of limonene and karinjin enhanced the insecticidal activity and mortality was also found to

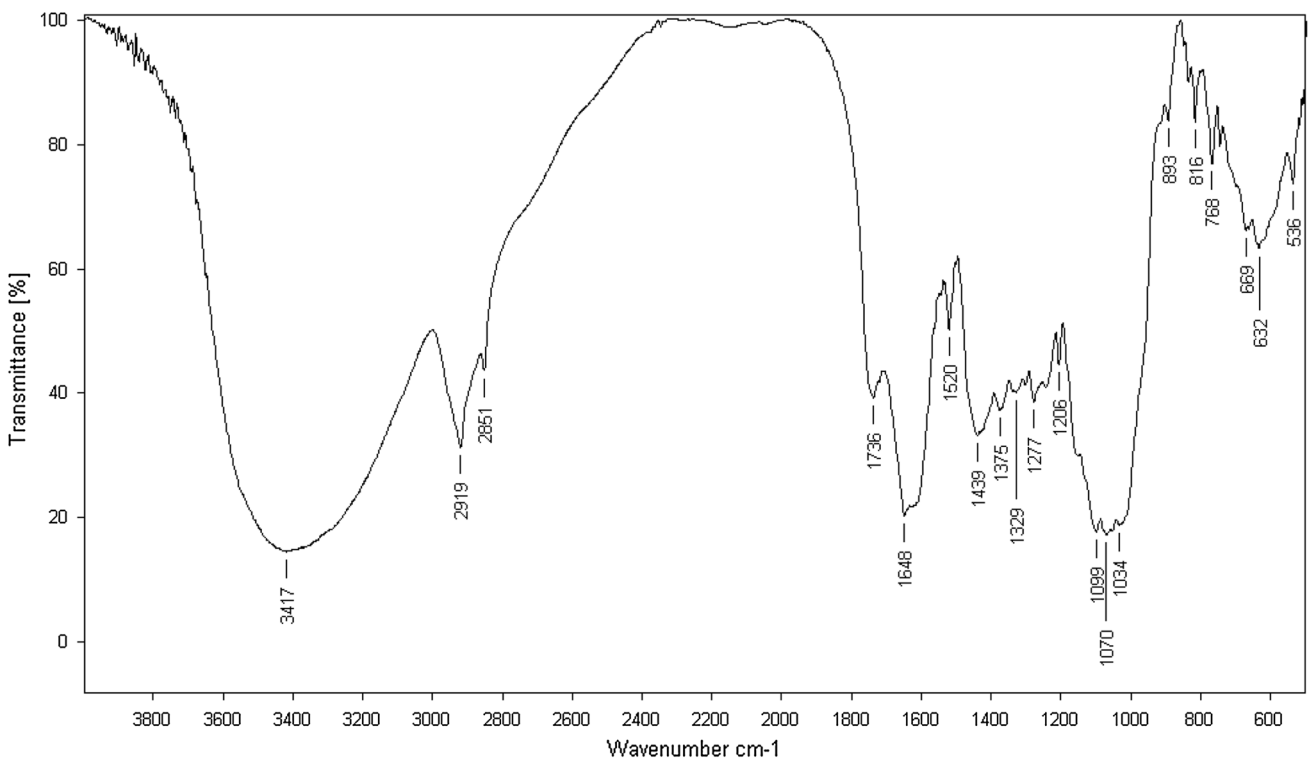



**Fig. 3** ATIR-FTIR spectra of tablet containing OP, KCP and JCP

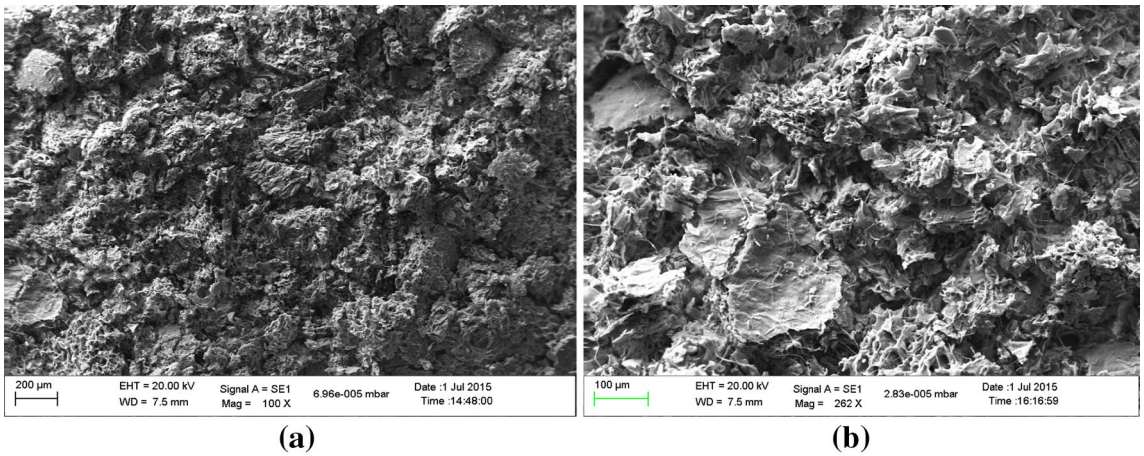



**Fig. 4** **a** SEM photographs of tablet containing OP, KCP, JCP and UTL, **b** SEM photographs of tablet containing OP and UTL

**Table 1** Statistical evaluation of the percentage mortality data of tablets containing OP + UTL + glucose in comparison with commercially available synthetic and botanical products for American cockroach with mean and standard error

| Sample name (tablets) | Replicates (N) | Mean% mortality with standard error (after 24 h) | Mean % mortality with standard error (after 48 h) | Mean % mortality with standard error (after 72 h) | Mean % mortality with standard error (after 96 h) |
|---|---|---|---|---|---|
| OP + UTL + glucose | 3 | $6.14 \pm 2.89^{b}$ | $21.14 \pm 2.89^{c}$ | $46.92 \pm 2.89^{b}$ | $68.85 \pm 2.89^{a}$ |
| Fipronil gel | 3 | $35.21 \pm 2.89^{a}$ | $59.00 \pm 2.89^{a}$ | $61.21 \pm 2.89^{a}$ | $68.85 \pm 2.89^{a}$ |
| Neemka paste | 3 | $28.78 \pm 2.89^{a}$ | $35.21 \pm 2.89^{b}$ | $46.92 \pm 2.89^{b}$ | $54.78 \pm 2.89^{b}$ |
| Control | 3 | $0.00 \pm 2.89^{b}$ | $0.00 \pm 2.89^{d}$ | $0.00 \pm 2.89^{c}$ | $0.00 \pm 2.89^{c}$ |

Mean ± SE with same superscript letter are not significantly different at $p < 0.05$ by DMRT

**Table 2** Statistical evaluation of the percentage mortality data of tablets containing OP + UTL + KCP + JCP + glucose in comparison with commercially available synthetic and botanical products for American cockroach with mean and standard error

| Sample name (tablets) | Replicates (N) | Mean% mortality with standard error (after 24 h) | Mean % mortality with standard error (after 48 h) | Mean % mortality with standard error (after 72 h) | Mean % mortality with standard error (after 96 h) |
|---|---|---|---|---|---|
| OP + UTL + KCP + JCP + glucose | 3 | $41.15 \pm 2.89^{a}$ | $52.77 \pm 2.89^{a}$ | $66.14 \pm 2.89^{a}$ | $90.00 \pm 2.35^{a}$ |
| Fipronil gel | 3 | $35.21 \pm 2.89^{ab}$ | $59.00 \pm 2.89^{a}$ | $61.21 \pm 2.89^{a}$ | $68.85 \pm 2.35^{b}$ |
| Neemka paste | 3 | $28.78 \pm 2.89^{b}$ | $35.21 \pm 2.89^{b}$ | $46.92 \pm 2.89^{b}$ | $54.78 \pm 2.35^{c}$ |
| Control | 3 | $0.00 \pm 2.89^{c}$ | $0.00 \pm 2.89^{c}$ | $0.00 \pm 2.89^{c}$ | $0.00 \pm 2.35^{d}$ |

Mean ± SE with same superscript letter are not significantly different at $p < 0.05$ by DMRT

be 100% within 96 h (Table 1).It was found KD50 values gradually decreased to 25.9597 min with the incorporation of KCP and JCP in tablet composition as compared to tablet containing OP and UTL (Table 2), where it was found to be 50.6697 min. The KD50 values of tablet composition with and without KCP and JCP were also compared with the KD50 value of commercially available synthetic and botanical products i.e. fipronil gel and neemka which was reported to be 29.971 and 63.5907 min respectively.

A Botanical tablet consists of ingredients derived from naturally occurring plant wastes. Various compositions were obtained by mixing different botanical waste based active ingredients. In one of the compositions, feeding attractant, glucose was mixed with the insecticide to attract the pest. These botanical wastes when used in different combinations cause behavioural and physiological abnormalities disrupting the metabolism, digestion leading to starvation and ultimately death (Fig. 5).

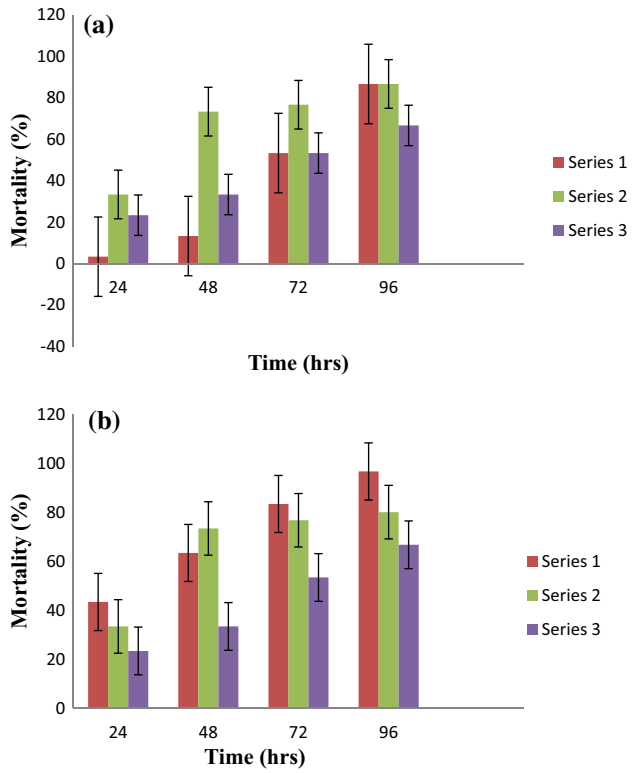



**Fig. 5** **a** Percentage mortality at different time intervals, **b** percentage mortality at different time intervals

## Conclusion

Tablets prepared using these botanical by-products as active ingredients are less toxic, eco-friendly and economical as compared to commercially available synthetic as well as botanical products. The paper mainly focuses on the efficient use of orange peel and biodiesel product, having insecticidal activity, which would otherwise cause waste disposal problems.

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