Uttar Pradesh Journal of Zoology

Volume 45, Issue 4, Page 193-204, 2024; Article no.UPJOZ.3258
ISSN: 0256-971X (P)

Assessment of Piscicidal Potentials of *Carica papaya* (Linnaeus, 1753) Leaves, Seeds, and Peel Powder on Juveniles of *Clarias gariepinus* (Burchell, 1822)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.56557/UPJOZ/2024/v45i43922

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://prh.mbimph.com/review-history/3258

Original Research Article

Received: 14/12/2023
Accepted: 19/02/2024
Published: 24/02/2024

ABSTRACT

In aquaculture, piscicides are used as fishing gear to combat parasitic, invasive fish species and eliminate dominant fish species in a water body. Therefore, assessment of piscicide activity is important. Hence, in this study, we have aimed to assess the piscicidal potential of *Carica papaya* leaves, seeds, and peel powder on juveniles of *Clarias gariepinus* using behavioural responses and mortality rate as the toxicity endpoints. Four hundred and fifty (450) juveniles of *Clarias gariepinus* were used for the 96-hour static bioassay. Five (5) different concentrations of 0 mgL^{-1}, 25 mgL^{-1}, 50

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mgL^{-1}, 75 mgL^{-1}, and 100 mgL^{-1} containing ten (10) fish samples in triplicates were used. The physicochemical parameters of the test concentrations monitored during the exposure include Temperature, pH, Electrical Conductivity, Dissolved Oxygen, and Total Dissolved Solids. The results of the physicochemical parameters did not vary significantly compared with the control. The results of the behavioural responses showed a range of reactions, such as erratic swimming, gulping of air, loss of reflex, vertical orientation, loss of buoyancy, jumping, and discolouration. The fish mortality rate was used to determine the median lethal concentrations (LC50) of the leaves, seeds, and peel powder using the Probit method. The LC50 values estimated from Probit analysis were 147.17 mgL^{-1}, 262.376 mgL^{-1}, and 697.180 mgL^{-1}, respectively. The results implied that of the three plant parts used, the leaves powder of *Carica papaya* showed the most promising piscicidal potential. Hence, this underscores screening whole plant parts to ascertain the most suitable for such desired activity. The substitutes of plant substances, which can act as ecologically friendly piscicides, can be encouraged against commonly used synthetic chemicals which can be detrimental to aquatic ecosystems.

Keywords: Behavioural responses; Carica papaya; powder; Clarias gariepinus; piscicidal.

1. INTRODUCTION

Over the years, synthetic piscicides have been used in aquaculture practices, which are toxic to fish and the aquatic ecosystem; the quest for natural piscicides to manage fish population and disease has led to the exploration of plant-based piscicides [1]. [2] defined an appropriate piscicide as one that effectively eliminates organisms at low doses, ensures safety for individuals and livestock, does not compromise fish suitability for human consumption, dissipates rapidly in water, does not have cumulative adverse impacts on the pond, and is easily accessible and cost-effective. Plants have an extensive capacity to produce biologically active chemicals, and the documented evidence supports the potential of plants for both medicinal and piscicidal purposes [3], [4]. Piscicidal plants have gained popularity in commercial fishing worldwide, including Nigeria, in recent years [5]. Common piscicidal plants that have been used in harvesting fish by fisherfolks include *Tetrapleura tetraptera, Blighia sapida*, *Raphia vinifera*, *Parkia biglobosa,* and *Kigelia africana* [6]. The plant parts reported to have piscicidal properties include fruits, seeds, leaves, bark, and roots [6]. Also, the active ingredients in the plant parts are said to have different capacities in harvesting fish, and the mode of action depends on the methods of application, which could be directly in the form of aqueous extract, powder, or dissolved in alcohol [7]. Generally, the active ingredients in piscicidal plants are alkaloids, tannins, resins, saponins, carpine, papain, nicotine, and rotenone [8, 9] which are reported to be toxic to fish at high concentrations and wear off within a short time, unlike synthetic chemicals [10,9]. Some of these plants possess ichthyotoxic properties, which make them very effective for capturing or immobilizing fish [11,12] found that exposure to botanicals can cause stress in fish, characterized by physiological and biochemical changes that may be evident in chronic or active toxicity tests.

Carica papaya, also known as Pawpaw, is a commoner's fruit available throughout the year in the tropics [13]. The plant has acquired common names such as "medicine tree" or "melon of health" because of its efficacy in numerous studies as an effective remedy for various tropical ailments, including its seeds, fruits, leaves, and latex [14,15,13]. The fleshy fruit is highly regarded for its nutritional value and is commonly used in nutrient-rich beverages. However, active compounds like carpine and papain from pawpaw fruit have hazardous properties [13], and large quantities of Carpine in the seeds depress the nervous system and reduce the pulse. According to [16], the phytochemical examination of the seed extract of *Carica papaya* showed that it contains flavonoids, alkaloids, tannins, steroids, and terpenoids with no saponins, while the leaf extract revealed active ingredients of flavonoids, alkaloids, tannins, saponins, and steroids with no terpenoids. In another report, the fruit peel extract was shown to contain active substances like saponins, steroids, sterols, and flavonoids [17].

According to [18], conventional fishermen use synthetic piscicides and other detrimental methods to capture fish to fulfil the country's protein requirements. Using these synthetic chemicals contaminates the water bodies' use for domestic purposes, disrupts the ecological balance of water, alters both the physical and chemical parameters of the water, reduces the taste and protein quality of fish, and can, in turn, affect man adversely in the food web [19]. Hence, there is a need to provide a substitute for synthetic chemicals. [20] argue that plant-derived piscicides are more environmentally friendly than chemical toxicants due to their biodegradable nature and potential fertilizer applications. These substances are considered safer for farmers and non-target species, do not contribute to resistance development, are readily biodegradable, and have minimal environmental side effects compared to synthetic ones [21]. However, the current perspective lacks substantial support from comprehensive research investigations due to their limited focus on examining synthetic piscicides such as rotenone, aldrin, dieldrin, endrin, cyanides, quick lime, and potassium permanganate [21].

The African Catfish, *Clarias gariepinus,* is a commercially important fish in the Nigerian fisheries industry and of significant ecological relevance [18]. However, it has proven to be a suitable bioindicator species for use in ecotoxicological studies involving synthetic chemicals and plant extracts [13], [18], [22], [23] due to its hardiness and ease of maintenance in laboratory conditions, sensitivity to swift changes in the aquatic environment, and link to humans via the food chain.

Previous research on the piscicidal and toxic activities of *C. papaya* seed powder extract [13], [18], [24- [26], fruit extract [15], leaf extract [11], [27,28] and root extract [29] on fish are well documented. Based on previous research, this study did not focus on analyzing the active components of *C. papaya.* Instead, the primary objective was to confirm and compare the piscicidal properties of the leaves, seeds, and fruit peel powder, to determine which part of the plant could be most effectively utilized as a piscicide in aquaculture.

2. MATERIALS AND METHODS

2.1 Plant Collection

The plant parts (leaves, seeds, and fruit peel) of *C. papaya* were obtained from the neighborhood around the World Health Organization Complex, Phase 2, Lokongoma, Lokoja, in Kogi State. For proper identification, all the plant parts were correctly identified at the Herbarium unit of the Department of Biological Sciences, Federal University Lokoja, with the assistance of experts.

2.2 Preparation of *C. papaya* Leaves, Seeds, and Peel Powder

The leaves, seeds, and fruit peels were air-dried at room temperature for 2 weeks to attain a constant weight. The leaves, seeds, and peels were blended to a fine powder using an electric blender and kept in a desiccator until the time of the experiment.

2.3 Fish Collection and Acclimatization

A total of four hundred and fifty (450) juveniles of *Clarias gariepinus* with a mean length (11.00 ± 1.50) cm and mean weight (10.00 ± 1.85) g were used in this study. The fish samples were obtained from a Private Fish Farm in Lokoja, Kogi State, Nigeria, and transported to the Laboratory with open plastic containers covered with nets. The fish were acclimatized for two weeks before the commencement of the experiment. The holding tanks were clean, and the water was renewed once in three days. The test fish were fed 5% based on their body weight twice daily, using formulated fish feed (40% protein) with Coppen Fish Feed Mill. Feeding was stopped 24 hours before the experiment and throughout the entire period of the 96-hour acute toxicity bioassay [30,31].

2.4 Experimental Design

The experiment used four hundred and fifty (450) *Clarias gariepinus* juveniles. One hundred fifty (150) juveniles of *Clarias gariepinus* were used each for the leave, seeds, and peel powder. Five different concentrations ($0mgL^{-1}$, $25mgL^{-1}$, $50mgL^{-1}$, $75mgL^{-1,}$ and $100mgL^{-1}$) were prepared in triplicates, containing ten (10) fish samples for the bioassay [32]. Distilled water was used as the solvent for the different concentrations, and the bioassay was conducted in rectangular plastic tanks of 50 litres capacity each.

2.5 Analysis of Physicochemical Parameters

The physicochemical parameters of different test concentrations were monitored daily for the 96-hour acute toxicity bioassay. They include Electrical Conductivity (μS/cm), Temperature (º C), pH, Dissolved Oxygen (mg/L), and Total Dissolved Solids (mg/L). All analyses followed standard procedures described by USEPA [33].

2.6 Acute Toxicity Test

The Organization for Economic Co-operation and Development [32] procedure was used to conduct the piscicidal test of *C. papaya* leaves, seeds, and peel powder. The static bioassay was used for the toxicity test, whereby there was no aeration, water change, or feeding throughout the test period. The acute toxicity test measured fish mortality and behavioural changes over 96 hours. The lethal concentration (LC_{50}) was determined using the Probit method, which estimates the concentration of test plant parts that cause 50% mortality of the test organisms [34]. The inability of fish to respond to external stimuli was considered a mortality indicator.

2.7 Statistical Analysis

The results of the physicochemical measured during the bioassay were presented as mean ± SD. Analysis of variance (ANOVA) was used to test for the significance difference at the 0.05 level of probability, and a post-hoc test was used to separate the means of the *Carica papaya* leaves, seeds, and peel powder concentrations. The Probit method determined the LC_{50} of the leaf, seed, and peel powder test concentrations as described by [18]. All the analyses were done using Statistical Package for Social Science (SPSS) 27.0 for Windows XP on PC.

3. RESULTS

3.1 Analysis of Physicochemical Parameters

The results of physicochemical parameters of the different concentrations of *Carica papaya* leaves, seeds, and peel powder throughout the 96-hour bioassay are presented in Tables 1, 2, and 3, respectively. The physicochemical parameters monitored for different concentrations of the Leaf powder for 96 hours showed no significant difference for all parameters between the control and 100mgl^{-1} concentrations except for electrical conductivity. The physiochemical parameters monitored in concentrations of the seed powder for 96 hours showed no significant difference for all concentrations. Also, the physicochemical parameters of concentrations of the peel powder monitored for 96 hours showed no significant difference between the concentrations.

3.2 Behavioural Responses of Fish Exposed to Different Concentrations of *C. papaya* Leaves, Seeds, and Peel Powder

Table 4 presents the behavioural responses of *Clarias gariepinus* juveniles to various concentrations of leaf powder of *Carica papaya*, which had adverse effects on the behaviour of the experimental fish with increased concentrations. The behavioural changes observed were erratic swimming, gulping of air, loss of reflex, abnormal vertical orientation, abnormal surface behaviour, loss of buoyancy control, and abnormal skin pigmentation. The behavioural responses were dose-dependent and time-dependent. Table 5 presents the behavioural responses of *Clarias gariepinus* juveniles to various concentrations of seeds powder of *Carica papaya,* which was concentration and time-dependent. The behavioural changes include erratic swimming, gulping of air, loss of reflex, abnormal vertical orientation, abnormal surface behaviour, loss of buoyancy control, and abnormal skin pigmentation.

Table 6 shows the behavioural responses of *Clarias gariepinus* juveniles to different concentrations of peel powder of *Carica papaya,* which showed little effect on behavioural changes with increasing concentrations. The behavioural changes observed were erratic swimming from 24 to 96 hours, ranging from low to moderate severity. Gulping of air, loss of reflex, abnormal vertical orientation, abnormal surface behaviour, and loss of buoyancy showed no significant difference within 24 to 48 hours of exposure. Skin pigmentation was not observed in all concentrations from 24 to 96 hours of exposure to the *C. papaya* peel powder.

Fig 1 shows the percentage of mortality of *Clarias gariepinus* exposed to different concentrations of leaves, seeds, and peel powder of *C. papaya*. For fish exposed to leaves powder, the highest concentration, 100mgL^{-1}, had the highest mortality rate (46.67 %) at the end of the exposure. The highest mortality rate for fish exposed to seed powder (26.67 %) was 100mgl^{-1}. In fish exposed to peel powder, there were no mortalities in the control and 100mgL^{-1} concentrations. However, the highest mortality rate (13.33 %) was 75 mgL^{-1}.

The Probit method was used to estimate the lethal concentrations (LC_{50}) for leaves, seeds, and peel powder concentrations, which were estimated to be 147.17mgL^{-1}, 262.376mgL^{-1}, and 697.180 mgL^{-1}, respectively.

Table 1. Mean (±SD) physicochemical parameters of the different concentrations of *C. papaya* leaves powder during the 96-hour acute toxicity bioassay

S/NO	Concentrations (mgL^{-1})	pH	Temperature (ºC)	Dissolved Oxygen (mgL^{-1})	Electrical Conductivity (µS/cm)	Total Dissolved Solids (mgL^{-1})
	0	7.84±0.13^{a}	28.7±1.24^{b}	3.32±2.11^{a}	645.40±70.74^{ab}	322.47±36.51^{ab}
	25	7.83±0.11^{a}	28.4±1.14^{ab}	2.91±1.45^{a}	642.40±65.81^{ab}	322.00±32.50^{ab}
	50	7.86±0.11^{a}	28.0±1.05^{ab}	3.41±1.16^{a}	617.20±49.12^{a}	311.13±24.62^{a}
	75	7.84±0.11^{a}	27.6±1.21^{a}	2.83±1.72^{a}	653.53±65.13^{ab}	327.87±32.08^{ab}
	100	7.79±0.09^{a}	27.8±1.18^{ab}	2.75±1.33^{a}	681.20±75.17^{b}	340.27±38.13^{ba}

Table 2. Mean (±SD) physicochemical parameters of the different concentrations of *C. papaya* seeds powder during the 96-hour acute toxicity bioassay

S/NO	Concentration (mgL^{-1})	pH	Temperature (ºC)	Dissolved Oxygen (mgL^{-1})	Electrical Conductivity (µS/cm)	Total Dissolved Solids (mgL^{-1})
1	0	7.92±0.18^{a}	28.7±1.24^{b}	4.71±1.34^{b}	257.99.0±47.77^{a}	306.80±29.24^{a}
2	25	7.92±0.10^{a}	27.8±1.50^{b}	3.40±1.60^{ab}	268.87±75.97^{a}	322.40±35.47^{a}
3	50	7.94±0.24^{a}	27.1±2.33^{ab}	3.41±1.82^{ab}	621.33±58.71^{a}	315.93±30.55^{a}
4	75	7.85±785^{a}	26.3±1.82^{a}	3.59±1.83^{ab}	624.84±62.95^{a}	321.80±31.46^{a}
5	100	7.84±0.31^{a}	27.2±0.76^{ab}	3.08±1.91^{a}	643.73±57.29^{a}	327.20±34.20^{a}

Table 3. Mean (±SD) physicochemical parameters of the different concentrations of *C. papaya* peel powder during the 96-hour acute toxicity bioassay

S/NO	Concentration (mgL^{-1})	pH	Temperature (ºC)	Dissolved Oxygen (mgL^{-1})	Electrical Conductivity (µS/cm)	Total Dissolved Solids (mgL^{-1})
1	0	7.46±0.82^{b}	25.9±0.73^{a}	4.4±1.64^{c}	244.6±102.91^{a}	124.1±53.30^{a}
2	25	7.38±0.14^{ab}	25.9±0.73^{a}	3.92±0.81^{bc}	212.0±74.20^{a}	101.6±32.84^{a}
3	50	7.34±0.10^{a}	25.9±0.42^{a}	3.57±0.75^{b}	230.6±77.78^{a}	114.1±39.76^{a}
4	75	7.36±0.11^{a}	26.2±0.352^{a}	3.27±1.01^{b}	208. 53±52.56^{a}	104.33±26.42^{a}
5	100	7.36±7.36^{a}	26.3±0.60^{a}	2.29±1.10^{a}	246.20±82.22^{a}	123.27±41.42^{a}

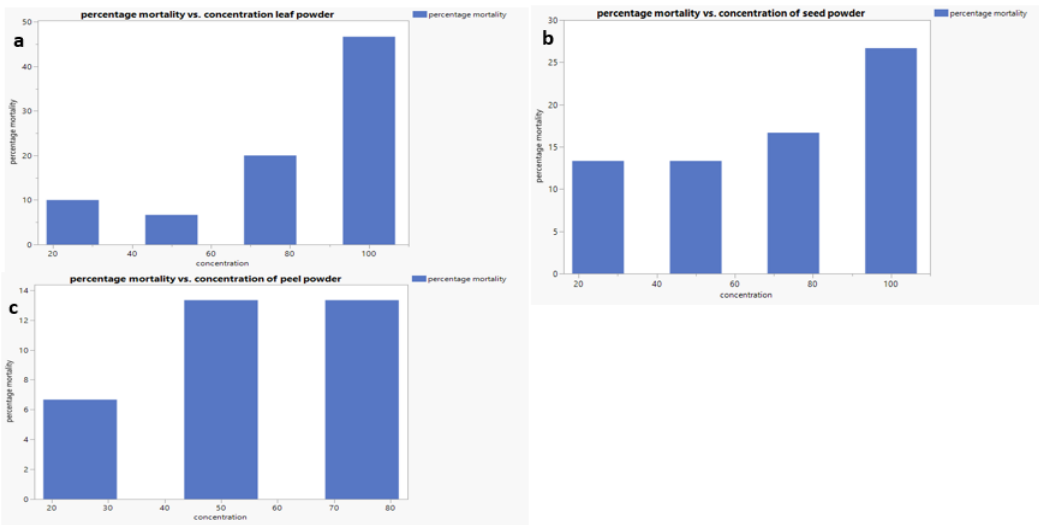

Fig. 1. Percentage mortality of *C. gariepinus* exposed to different concentrations of *C. papaya* leaves powder (a), seeds powder (b), and peel powder (c) during the 96-hour acute toxicity bioassay

Table 4. Behavioral changes of *Clarias gariepinus* juveniles exposed to varied concentrations of *C. papaya* leaves powder during the 96-hour acute toxicity bioassay

Exposure time (hr)	Conc. (mg/L)	Behavioural Responses						
		Erratic swimming	Air gulping	Loss of reflex	Abnormal vertical orientation	Jumping	Loss of buoyancy	Discolouration
24 hr	0	-	-	-	-	-	-	-
	25	+	-	-	-	-	-	-
	50	+	-	-	-	+	-	-
	75	+	-	-	-	+	-	-
	100	+	-	-	-	+	-	-
48 hr	0	-	-	-	-	-	-	-
	25	+	+	+	+	-	+	-
	50	+	+	+	+	+	+	+
	75	+	+	+	+	+	+	+
	100	+	+	+	+	+	+	+
72 hr	0	-	-	-	-	-	-	-
	25	+	+	++	+	+	++	++
	50	+	++	++	++	+	++	++
	75	++	+++	+++	+++	++	++	+++
	100	++	+++	+++	+++	++	+++	+++
96 hr	0	-	-	-	-	-	-	-
	25	+	+++	++	++	+	++	+++
	50	++	+++	+++	+++	++	+++	+++
	75	++	+++	+++	+++	++	+++	+++
	100	++	+++	+++	+++	++	+++	+++

Where - = no significant sign, + = low severity, ++ = moderate severity, +++ = high severity

Table 5. Behavioral changes of *Clarias gariepinus* juveniles exposed to varied *C. papaya* seeds powder concentrations during the 96-hour acute toxicity bioassay

Exposure time (hr)	Conc. (mg/L)	Behavioural Responses						
		Erratic swimming	Air gulping	Loss of reflex	Abnormal vertical orientation	Jumping	Loss of buoyancy	Discolouration
24 hr	0	-	-	-	-	-	-	-
	25	+	-	-	-	+	-	-
	50	+	-	-	-	+	-	-
	75	+	-	-	-	+	-	-
	100	+	-	-	-	+	-	-
48 hr	0	-	-	-	-	-	-	-
	25	+	+	-	+	+	+	-
	50	+	+	-	+	+	+	-
	75	+	+	-	+	+	+	-
	100	+	+	-	+	+	+	++
72 hr	0	-	-	-	-	-	-	-
	25	+	+	++	++	++	++	++
	50	+	++	++	++	++	++	++
	75	++	++	++	++	++	++	++
	100	++	++	+++	++	++	+++	+++
96 hr	0	-	-	-	-	-	-	-
	25	+	++	++	++	+	++	++
	50	++	+++	+++	++	++	++	++
	75	++	+++	+++	+++	+++	+++	+++
	100	++	+++	+++	+++	+++	+++	+++

where - = no significant sign, + = low severity, ++ = moderate severity, +++ = high severity

Table 6. Behavioral changes of *Clarias gariepinus* juveniles exposed to Varied *C. Papaya* peel powder concentrations during the 96-hour acute toxicity bioassay

Exposure time (hr)	Conc. (mg/L)	Behavioural Responses						
		Erratic swimming	Air gulping	Loss of reflex	Abnormal vertical orientation	Jumping	Loss of buoyancy	Discolouration
24 hr	0	-	-	-	-	-	-	-
	25	+	-	-	-	-	-	-
	50	+	-	-	-	-	-	-
	75	+	-	-	-	-	-	-
	100	+	-	-	-	-	-	-
48 hr	0	-	-	-	-	-	-	-
	25	+	-	-	-	-	-	-
	50	+	-	-	-	-	-	-
	75	+	-	-	-	-	-	-
	100	+	-	-	-	-	-	-
72 hr	0	-	-	-	-	-	-	-
	25	+	+	+	+	+	+	-
	50	+	+	+	+	+	+	-
	75	++	+	+	++	++	+	-
	100	++	+	+	+++	++	+	-
96 hr	0	-	-	-	-	-	-	-
	25	++	++	++	++	++	+	-
	50	++	++	++	++	++	+	-
	75	++	++	++	++	++	+	-
	100	++	++	++	++	++	+	-

Where - = no significant sign, + = low severity, ++ = moderate severity, +++ = high severity

4. DISCUSSION

Aquatic ecotoxicology frequently uses toxicity bioassays to determine toxic substances' threshold levels for aquatic organisms and predict their impact and fate, including botanicals. To our knowledge, this is not the first toxicological examination of extracts of *C. papaya* parts. Still, our study primarily sought to assess the piscicidal potential of the leaf, seed, and peel powder directly, without any form of processing, on the juveniles of *Clarias gariepinus*. Our observed values of the direct application of the powder of the leaves, seeds, and fruit peel of *C. papaya* on juveniles of *Clarias gariepinus* compare slightly differently from those reported on fingerlings and adults of the same and other species [13], [18], [24], [25]. The piscicidal potential of all the tested plant parts elicited some behavioural responses in the juveniles of *C. papaya* in the form of erratic swimming, air gulping, loss of reflex, vertical surface orientation, loss of buoyancy, jumping, and discolouration. Although there were no significant differences in the physicochemical parameters, introducing the powder directly into the water could have led to stress factors that could have triggered such behavioural responses in the test fish. The observed behavioural changes are indicators of physiological stress in fish, which could result from the toxic properties of the *C. papaya* part powder. Similar behavioural responses were observed and reported by [24, 25] when they exposed extracts of *C. papaya* seed powder to fingerlings and adults of the Nile Tilapia *Oreochromis niloticus*. Also, this result agrees with the findings of [13], [18]), who exposed *C. papaya* seed powder to fingerlings and adults of *Clarias gariepinus,* respectively, and [28], who exposed dried pawpaw leaves extract to the fingerlings of *C. gariepinus*. The behavioural responses observed were also similar to those observed with different plant extracts by [35], and [36], who exposed leaf powder extract of *Tetrapleura tetrepleura* and fruit extract of *Luffa cylindrica* to fingerlings of *C. gariepinus,* respectively, and leaf extract of *Hypoestes forskaolii* [37]. The observed erratic behaviours could be a result of the presence of active ingredients such as flavonoids, alkaloids, tannins, saponins, steroids, and terpenoids present in the leaves and seeds of *C. papaya* [16]. The behavioural responses like air gulping, loss of reflex, erratic swimming, jumping, and loss of buoyancy increased with an increase in concentrations of the leave and seeds powder than in the peel powder, indicating that such responses are concentration dependent, which agrees with the report of [26]. The gulping of air and loss of reflex observed in the fish before death could indicate the depletion of dissolved oxygen in the test concentrations since it is one of the most important factors for fish to survive in their habitat. [23] reported that behavioural aberrations could indicate internal disturbance in the exposed fish, which suggests an impairment in the respiratory system and metabolic processes. Through the exposure period, no change was observed in the discolouration of fish exposed to different concentrations of the peel powder, which could indicate less toxic properties of the peels. However, the discolouration increased as the leaf and seed powder concentrations increased, indicating that the active ingredients in the plant parts could have interfered with the pigments responsible for maintaining the skin colour.

There were no mortalities in the control concentrations, but the percentage mortality observed in the different test concentrations indicated dependence on the time of exposure and dose of concentration. This result corroborates past findings [18], [23], [25], [26], [36], [38], [39] with different plant parts extracts and environmental pollutants.

The 96-hour LC_{50} of 147.17mgL^{-1} for leaves powder estimated in this study was lower than the 48-hour LC_{50} 2.16 gL^{-1} (2160 mgL^{-1}) of *C. papaya* aqueous leaves extract reported by [40], who screened five different plants leaf extracts for their piscicidal properties. [28] reported an LC_{50} of 10.9 ml/L for pawpaw aqueous leaves extract, which is lower than the 147.17 mgL^{-1} estimated for leaves powder in this study. [25] reported an LC_{50} of 4.2 mgL^{-1} for seeds powder solution exposed to adult *Oreochromis niloticus,* far lower than the 262.376 mgL^{-1} for seeds powder estimated in this study. An LC_{50} of 3.3mgL^{-1} for aqueous extract of pawpaw seeds powder was reported by [18], which was lower than the 262.37 mgL^{-1} estimated for seeds powder. [26] reported an LC_{50} of 163.02 mgL^{-1} for aqueous seeds extract of *C. papaya* seeds exposed to juveniles of *Clarias gariepinus,* which was lower than the 262.37 mgL^{-1} obtained in this study. The 96-hour LC_{50} for the *C. papaya* fruit peel powder estimated from this study was 697.180 mgL^{-1}, the highest of the three plant parts examined. This indicated it had the least piscicidal potential of the three examined parts. There are no previous works on the effects of *C. papaya* fruit peel powder on fish whose results could be compared with our findings. Still, we believe this could serve as a reference for future researchers intending to use the peels as piscicides in aquaculture. Generally, the differences observed in the median lethal concentrations compared with previous studies could be due to the methods of preparation of the different plant parts and test concentrations used.

5. CONCLUSION

The study examined the piscicidal potentials of *Carica papaya* leaves, seeds, and fruit peel powder on the juveniles of *Clarias gariepinus*. Overall, the study suggests that all three plant parts of *Carica papaya* have potential as piscicidal agents, with the leaves powder being the most effective. We, therefore, conclude that rather than go for harmful synthetic chemicals for harvesting fish, safe, environmentally friendly substitutes, like plant extracts and powders, can be used by fish farmers to eradicate unwanted or invasive fish from nursery and rearing ponds before stocking in aquaculture. Further research is needed to determine these plant parts' optimal concentration and application method to maximize their efficacy while minimizing their potential environmental impacts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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