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Analyzing the Ability of Various Chosen Medicinal Herbs to Cure Wounds in African Catfish (*Clarias gariepinus*, Burchell 1822)

Adebisi Musefiu Tiamiyu[1]*, Folusho B. Bolaji-Alabi[2], Reuben Chukuwa Okocha[3], Isaac Olufemi Olatoye[4] and Oluwafemi Bolarinwa Adedeji[4]

[1]Department of Biosciences and Biotechnology, Faculty of Science, University of Medical Sciences, Ondo City, Ondo State, Nigeria
[2]Department of Veterinary Surgery and Reproduction, Faculty of Veterinary Medicine, University of Ibadan, Ibadan, Oyo, Nigeria
[3]Department of Agriculture, College of Agriculture Studies, Landmark University, Km 4 Ipetu, Omu-Aran Road, Omu-Aran, Kwara State, Nigeria
[4]Department of Veterinary Public Health and Preventive Medicine, Faculty of Veterinary Medicine, University of Ibadan, Ibadan, Oyo, Nigeria

*Correspondence :
tiaadebisi2014@yahoo.com
atiamiyu@unimed.edu.ng

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Abstract

Phytomedicines are affordable, safe, and offer great potential for treating and controlling wounds. The effects of herbal supplements on *C. gariepinus* wound healing were investigated. Twenty-four fish (146.4±0.74g) randomized into four paired sub-groups: G_1 and G_2, G_3 and G_4, G_5 and G_6, G_7, and G_8 were fed formulated rations containing no herbal additive (0.0g/kg), 5.0g/kg of *Allium sativum*, 10.0g/kg of *Chromolaena odorata* and 10.0g/kg of *Talinum triangulare* as feed additive respectively at 5% body weight. On the 21st day, a sterile incision measuring 45.0 mm by 1.0 mm was made on the dorsolateral side of each fish. Subgroups G_2, G_4, G_6, and G_8 were intraperitoneally inoculated with 0.1 ml of pathogenic *Pseudomonas aeruginosa* that had been predetermined (1.4×10^6 bacteria/ml), while G_1, G_3, G_5, and G_7 were not inoculated. Post-incision, macroscopic parameters (measurements), given as percentage healing rates on days 3, 6, 9, 12, and 15, were used to evaluate the wound closure. Data were analyzed using descriptive statistics and ANOVA at α0.05. On day 3, there were significant differences between the control and treatment groups in the healing pattern ($P < 0.05$). On day 15 post-incision, G_7 had the best healing rate in both inoculated (86.7 percent) and uninoculated (100 percent) fish, while G_1 had the lowest healing rate (0.0 percent) and maximum healing rate (64.4 percent), respectively. The findings indicated that *T. triangulare* at a concentration of 10.0 g/kg was the optimum feed additive for promoting wound healing in *C. gariepinus*.

INTRODUCTION

Aquaculture supplies animal protein and is crucial for the world's economy and the food security of many people. Many communities around the world depend on fish and fish-related items for their livelihoods and income (Béné *et al.*,

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2009). The African catfish, also known as *C. gariepinus*, is a common aquaculture fish in Nigeria because of its high economic value, enticing flavor, and superior flesh quality. A fish with fast growth and resistance to harsh environmental conditions. According to Eissa *et al*. (2009), the rapid and continued expansion of all aquaculture sectors requires better health management and a better ability to deal with evolving health concerns. This is particularly clear in light of growing interest in species divergence and new grow-out methods. These industries are continually growing faster than education, research, and the application of knowledge in health management (Wang *et al*., 2017). Although we have made considerable improvements in the last 20–30 years in our capability to manage the majority of these health conditions, the ongoing encounters still mandate more progressions (Eissa *et al*., 2009).

African catfish, being aggressive, occasionally cause injuries on one another's bodies, specifically when kept in large quantities. A wound is an injury in which the skin or another external surface is torn, stabbed, carved, or otherwise impaired with disruption of the usual continuity of structures according to Saravanan *et al*. (2017). As a result, the permanency of the epithelium is lost, whether or not the underlying connective tissue is lost as well. Problems arise when wounds are perpetrated on the bodies of farmed fish because injured fish are more susceptible to predatory behavior (such as cannibalism) and because open wounds make it easier for infections to spread (Duk *et al*., 2017). One of the infections that spreads the fastest and is a main factor in the mass mortality of sick fish is bacterial infections (Eissa *et al*., 2010). Even though the majority of fish infections are water-borne, they can nevertheless be very hazardous to fish with enfeebled immune systems. Antibiotic use by many farmers and aquaculturists has led to the deterrence and control of bacterial infections in cultivated organisms (Zhang *et al*., 2021). However, excessive and unrestricted antibiotic usage has resulted in antibiotic residues in food fish and the creation of bacteria strains resistant to routinely used antibiotics (Nya and Austin, 2011; Aly and Albutti, 2014), which poses a hazard to the environment and the wellbeing of both humans and animals. Owing to their undesirable environmental effects, several synthetic substances used in aquaculture have been proscribed or debarred in various nations (Unuofin, 2020).

Secondary metabolites derivatives of plants have been revealed to be effective as healing agents against a diversity of animal, plant, and human illnesses in addition to their nutritional and food value, making plants more beneficial to animal and human lives (Ogbonnia *et al*., 2008). Herbs are exploited to cure a variety of diseases nowadays (Oz, 2010). Various herbs have great promise for managing and treating wounds. These organic preparations promote tissue regeneration and healing through a range of mechanisms (Rex *et al*., 2018). The habit of herbal remedies to cure illnesses is becoming more widespread since they are biodegradable, affordable, and have few undesirable effects (Ogbonnia *et al*., 2010). The immune system is enthused by medicinal herbs. These plants' secondary metabolites, which have defined biological effects on both the human and animal body, are what provide them with their healing properties.

In Africa, it is common to find medicinal plants that have been believed safe for consumers. These plants also play a significant part in aquaculture (Harikrishnan *et al*., 2011). Healing plants are exploited internationally due to their effectiveness against bacteria, fungi, and viruses (Paul and Roychoudhury, 2021), and modern studies have shown the significance of herbal items in fish farming (Rawling *et al*., 2009). There is currently a

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lot of interest in researching how plants affect pharmacology because they may have fewer negative side effects, reduced costs, and other advantages (Calixto, 2000), hence the effort to evaluate the dietary effects of some locally available plants on wound healing.

Garlic (*Allium sativum*) L., a member of the Alliaceae family, has long been valued as a valuable herb, documented as a spice, and used to treat a variety of illnesses and biological anomalies. Garlic has been shown to promote fish health largely and to control diseases like fungi and bacteria (Corzo-Martínez *et al*., 2007). Moreover, *A. sativum* has been established as a plant with the potential for wound healing (Bahramsoltani *et al*., 2014). In tropical parts of Africa, Siam weed (*C. odorata*) is believed to be a valuable herb for treating a variety of ailments, including fever, malaria, and toothaches (Taiwo *et al*., 2000). Siam weed leaf crude extract has in history been used as an antibacterial for bandages on wounds (Zachariades *et al*., 2009). Fresh sap from the leaf of *C. odorata* has been used as a hemostatic agent to stop fresh cuts and nasal bleeding, and it has been revealed to be effective in the management of wounds and hemorrhoids (Phan *et al*., 2001). Waterleaf (*T. triangulare*) is a common species in the tropics.

A non-traditional vegetable crop, it is generally cultivated in Western Africa, Southern America, and Asia. It originated in the tropics (Atibita *et al*., 2021). Beta-carotene, proteins, vitamins, minerals (including K, Ca, and Mg), and pectin are all found in *T. triangulare* (Ezekwe *et al*., 2013). It has been confirmed to have helpful medicinal properties, including laxative effects, the ability to treat diarrhea and gastrointestinal system maladies, as well as the capability to control cardiac conditions like stroke (Aja *et al*., 2010). As more medicinal plants have been found, scientists have been forced to examine their biological processes to offer information that would help farmers, veterinarians, and medical professionals make wise decisions about how to use the plants (Oyewole and Kingbala, 2011).

Aquaculture fish are vulnerable to tissue wounds from a variety of factors, including handling, illness, and conspecific biting. Wounding leads to poor health on the part of the fish and to the reduction of the fillets due to mostly poor visual appeal to the consumer (Noble *et al*., 2012). While wound healing, especially of fins, has been broadly studied in small model fish species such as the zebrafish, not much is known about wound healing in the larger species such as *C. gariepinus,* cultivated for consumption. The objective of this work was to assess the potential dietary effects of *A. sativum, C. odorata*, and *T. triangulare* on the dermal wound healing pattern in adult *C. gariepinus*.

METHODOLOGY

Ethical Approval

The ethical approval was acquired from the University of Ibadan Animal Care and Use for Research Ethical Committee. The approval number is UI-ACUREC/App/2015/066. The experiment was conducted according to ACUREC-approved protocol.

Place and Time

This research was conducted at the Wet Laboratory of the Department of Veterinary Public Health and Preventive Medicine, University of Ibadan, Ibadan, Oyo State, Nigeria in the year 2016.

Research Materials

The healthy sub-adult fish, *C. gariepinus* (n=24) of average weight 146 ±4.74g and length 27.76±0.28 cm was used as the experimental fish sourced from a local fish farm in Olodo, Oyo State of Nigeria. A circular tank with a 100-liter capacity was used to acclimatize the experimental fish for 14 days. Clean borehole water was used to fill the tank,

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and it was fed basic feed without any herbal plant additives twice daily. To get rid of ectoparasites, the fish were given a 1.0 milligram per liter $KMnO_4$ treatment.

A. sativum bulbs were obtained from Bodija markets in Ibadan, Oyo State, and healthy, fresh leaves of *C. odorata* and *T. triangulare* were collected from the wild in Okun-Owa, Ijebu-Ode, Ogun State. Both states (Oyo and Ogun) are in the southwestern region of Nigeria.

The plants were verified at the Department of Botany's herbarium at the University of Ibadan, where voucher specimens for *A. sativum*, *C. odorata*, and *T. triangulare* were deposited under the designations UIH-22536, UIH-22521, and UIH-22522, respectively, for future references.

Research Design

Four experimental diets were prepared by incorporating *A. sativum*, *C. odorata,* and *T. triangulare* at the following inclusion levels: Diet 1 (no plant powder added as a feed additive, tagged as control feed); Diet 2 (5.0g/kg of *A. sativum* added to the basic diet as a feed additive); Diet 3 (10.0g/kg of *C. odorata* added to the basic diet as a feed additive); and Diet 4 (10.0g/kg of *T. triangulare* added to the basic diet as a feed additive).

Work Procedure

Plant Preparation

Clean water was used to properly rinse the gathered plant leaves. The laboratory side bench was used to air dry the leaves for three weeks at a temperature of 25 ± 2°C before using a mechanical grinder to grind them into powder. Garlic bulbs were peeled, sliced into smaller pieces, and then dehydrated in an oven at 70 °C until they reached a constant weight. Using an electric food processor, the dried garlic was ground into a powder. The labeled plastic containers that were used to store the plant powder were airtight (Oo *et al*., 2019).

Experimental Diet Preparation

The basic diet was formulated with locally sourced feed materials; containing yellow corn (35), Soya-bean meal 44% (28.5), Fish meal 65% (17.0), wheat bran (9.5), Calcium carbonate (0.3), Ground limestone (0.7), Vegetable oil (6.5), Mineral combination (1.7) and Vitamin Combination (1.0). The feed materials were thoroughly mixed and ground into powdery form. The basic diet was analyzed and revealed nutrient composition in percentage: Dry matter (DM) 90.40, Crude protein (CP) 30.65, Ether extract (EE) 11.73, Ash 2.70, Crude fiber 10.11, Nitrogen-free extract (NFE) 44.81, Gross energy (Kcal/100 g DM) (GE) 467.77, and Protein/energy (P/E) ratio of (mg CP/Kcal GE) 65.52. Food was pelletized using a 0.5 mm wide pellet press. For four days, the foods were dried up and stored in airtight containers with the proper labels for use throughout the inquiry. The preliminary experiment testing the biosafety of the plants utilized for the trial in the culturing of *C. gariepinus* served as the basis for the decision on the amount of dried leaf powder to be added to the experimental diet.

Experimental Technique

Twenty-four (24) healthy sub-adult *C. gariepinus* were used for the experiment. The fish were randomized into eight groups; G_1, G_2, G_3, G_4, G_5, G_6, G_7 and G_8. Each group consists of three (3) freshwater African Catfish. Groups G_1 and G_2 were fed diet 1, a basic diet (control) containing no herbal extracts. Groups G_3 and G_4 were fed diet 2, feed containing 5.0g/kg of *A. sativum* as feed additives, Groups G_5 and G_6 were fed diet 3, feed containing 10.0g/kg of *C. odorata* as feed additives while Groups G_7 and G_8 were fed diet 4, feed containing 10.0g/kg of *T. triangulare* as feed additives. The feed embedded with herbs was fed *ad libitum* twice a day for 21 days. After rearing for 21 days, feeding was stopped 24 hours

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before surgery, the fish were anesthetized by immersion into 1 liter of cold water containing 200mg of tricane methane sulphonate (MS-222).

The dorsolateral part of the fish was aseptically prepared for surgery. The artificial wound was created for each of the experimental fish by the gently incised wound of 45.0 mm in length and 1.0 mm in depth using a sterile scalpel blade. The fish in the even number groups: G_2, G_4, G_6, and G_8 were injected with 0.1ml of already predetermined (1.4 x10^6 bacteria/ml) pathogenic *P. aeruginosa* intraperitoneally. After the surgical procedure, all the fish continued to be fed with the feed supplemented with medicinal plants except groups G_1 and G_2 which were fed a basic diet that served as negative and positive control respectively.

All the fish were left for observation. The wound closure was assessed using macroscopic parameters (measurements) at steady intervals of time, days 3, 6, 9, 12, and 15 after the sterile incision was created, and calculated as per hundred of wound closure and the establishment of fresh epithelial tissue indicates epithelization time. The period of epithelization is the number of days necessary for dropping the scar without any remaining fresh wound (Kokane *et al*., 2009) and this was calculated in line with the method previously used by Bazafkan *et al*. (2014).

$$\text{Wound Closure (\%)} = \frac{\text{initial wound area} - \text{wound area on } n^{th}\text{day}}{\text{initial wound area}}$$

Where:
n = days when observing the wound

Data Analysis

Graph Pad Prism Software Version 5.1 was used to analyze the data. Average values of the wound closure were measured. The results were presented as mean±SD. All measurements were subjected to an analysis of variance (ANOVA) and the Tukey Test was used to rank the means. P values less than 0.05 were considered significant.

RESULTS AND DISCUSSION

Wound restorative progression was assessed morphologically. The average length (mm) and percentage of wound closure in different treatment groups after the sterile incision was created were assessed and compared with those of negative and positive control groups within and without the medicinal plant-fed groups. The results of wound healing activity that resulted in a wound closure model are presented in Table 1.

Table 1. Average length (mm) of wound closure on experimental fish on days 3, 6, 9, 12, and 15 (Mean ± SD).

Group	Medicinal Plants Used	Quantity Fed	Days				
			3	6	9	12	15
#G_1	Negative Control	0.0g/kg	7.0±1.73	10.0±2.65	14.67±1.16	22.0±2.65	29.0±4.36
$^{\gamma\gamma\gamma}G_2$	Positive Control	0.0g/kg	5.0±2.00	NA	NA	NA	NA
$^{\gamma}G_3$	*A. sativum*	5g/kg	11.0±0.00	27.0±3.61*	31.33±1.16*	36.0±1.73*	41.0±1.73*
$^{\gamma\gamma}G_4$	*A. sativum*	5g/kg	15.0±3.00*	21.0±3.61*	25.00±4.58*	31.0±2.00	38.33±5.86*
$^{\gamma}G_5$	*C. odorata*	10g/kg	25.0±2.00*	31.0±2.65*	35.0±3.00*	38.0±2.00*	43.0±1.73*
$^{\gamma\gamma}G_6$	*C. odorata*	10g/kg	19.0±1.73*	26.0±2.65*	30.0±2.00*	33.0±1.00	35.0±1.00*
$^{\gamma}G_7$	*T. triangulare*	10g/kg	10.0±1.73	17.0±1.00	37.0±3.61*	43.67±1.53*	45.0±1.00
$^{\gamma\gamma}G_8$	*T. triangulare*	10g/kg	8.0±2.65	13.0±4.36	20.0±4.36	33.0±11.14	41.0±4.00

Notes: Mean values with the * superscript were significantly different (p<0.05) compared with the control. $^{\gamma}$Group fed an herbal diet without pathogenic *P. aeruginosa* injection; $^{\gamma\gamma}$Group fed the herbal diet with *P aeruginosa* injection; $^{\gamma\gamma\gamma}$Group fed without herbal diet with *P. aeruginosa* injection. # Group fed without herbal diet and without pathogenic *P.aeruginosa* injection. NA = Not Available.

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The fish in the positive control group (G_2) started to show abnormal signs post-18-hour injection. On the 3rd day, the fish developed spots on the lateral side, large brownish abrasions near the tail, and hemorrhagic spots near the pelvic region. The wounds eventually got contaminated, and by the fifth day, two of the fish in group G_2 died. The wound created in the remaining fish in G_2 got contaminated and measurements on the experimental fish in this group could not be taken on day 6 and beyond (Figure 1).

Figure 1. Contamination of the wound in positive control.

The wound closure in the groups fed with *A. sativum* additive without injecting *P. aeruginosa* (G_3) and the groups fed with *A. sativum* additive and injected with *P. aeruginosa* (G_4) healed appreciably better and significantly better when compared with control groups at day 6, 9, 12, and 15 (Figure 2). However, wound closure in G_3 was better than in G_4.

The rate of wound closure in groups of fish fed with *C. odorata* was faster than in the control group and it was significant. It was also observed that the group injected with *P. aeruginosa did* not heal as fast as the group not injected (Figure 3).

The wound of the fish in groups fed with *T. triangulare* also closed faster than in control groups. On day 15, complete wound closure was observed in a group of fish fed with 10.0g/kg *T. triangulare* but not injected with *P. aeruginosa,* G_7 (Figure 4).

In the macroscopic evaluation of the wound process, the percentage of wound healing on the 3^{rd}, 6^{th}, 9^{th}, 12^{th}, and 15^{th} days after the wound creation was evaluated and compared with those of the positive and negative control groups. The percentage of the rate of wound closure is shown in Table 2.

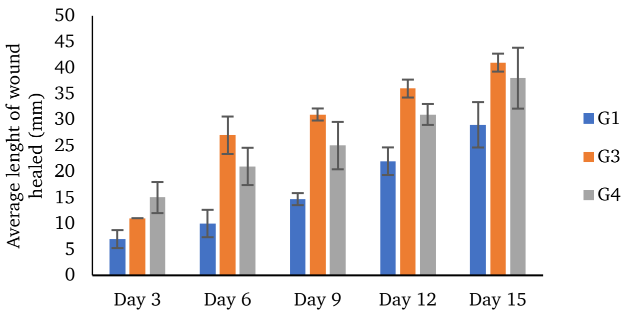

Figure 2. Different levels of wound healing in the experimental fish: G_1= Group fed without herbal diet and pathogenic *P. aeruginosa* injection (Negative Control); G_3 = Group fed with 5.0g/kg *A. sativum* additives without *P. aeruginosa* injection, G_4 = Group fed with 5.0g/kg *A. sativum* additives with *P. aeruginosa* injection.

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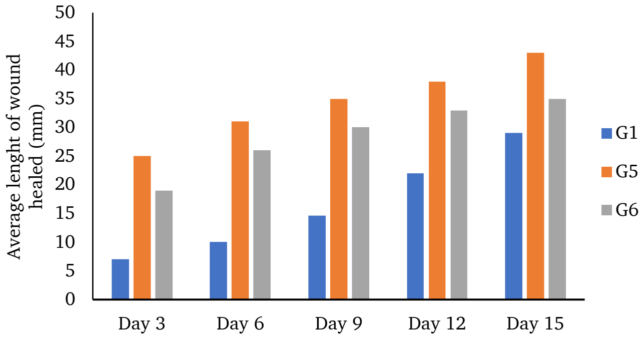

Figure 3. Different levels of wound healing in the experimental fish: G_1= Group fed without herbal diet and pathogenic *P. aeruginosa* injection (Negative Control); G_5 = Group fed with 10.0g/kg *C. odorata* additives without *P. aeruginosa* injection, G_6 = Group fed with 10.0g/kg *C. odorata* additives with *P. aeruginosa* injection.

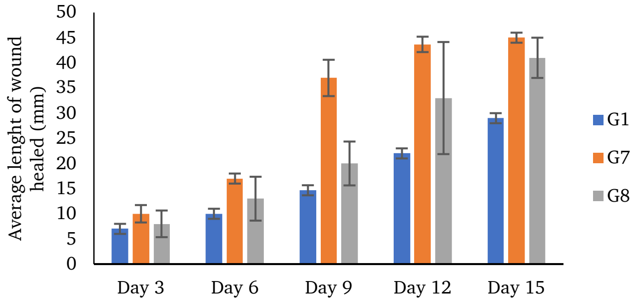

Figure 4. Different levels of wound healing in the experimental fish: G_1= Group fed without herbal diet and pathogenic *P. aeruginosa* injection (Negative Control); G_7 = Group fed with 10.0g/kg *T. triangulare* additives without *P. aeruginosa* injection, G_8 = Group fed with 10.0g/kg *T. triangulare* additives with *P. aeruginosa* injection.

Table 2. Comparison of average length of wound (mm) and percentage of wound closure.

Days	Groups of Experimental Fish							
	#G_1	ϒϒϒG_2	ϒG_3	ϒϒG_4	ϒG_5	ϒϒG_6	ϒG_7	ϒϒG_8
3	38(15.6)	40(11.1)	24(46.7)	30(33.3)	20(55.6)	26(42.2)	35(22.2)	37(17.8)
6	35(22.2)	NA	18(60.0)	24(46.7)	14(68.9)	19(57.8)	28(37.8)	32(28.9
9	30(33.3)	NA	13(71.1)	20(55.6)	10(77.8)	15(66.7)	8(82.2)	25(44.9)
12	23(48.9)	NA	9(80.0)	14(68.9)	7(84.4)	12(73.3)	2(95.6)	18(60.0)
15	16(64.4)	NA	4(91.1)	10(77.7)	2(95.6)	10(77.8)	0(100.0)	6(86.7)

Notes: ϒGroup fed herbal diet without pathogenic *P. aeruginosa* injection; ϒϒGroup fed the herbal diet with *P. aeruginosa* injection; ϒϒϒGroup fed without herbal diet with *P. aeruginosa* injection. # Group fed without herbal diet and pathogenic *P. aeruginosa* injection. (%) in parenthesis. NA = Not Available.

On the 6th day, the rate of healing was still fastest in *C. odorata* treated fish, G_5 (68.9%), followed by *A. sativum* treated fish, G_3 (60.0%). Other wounds improve as follows: G_6 (57.8%), G_4 (46.7%), G_7 (37.8%), G_8 (28.9%), and G_1 (22.2%). By the eighth day post-inflicted wound, the remaining fish in group G_2 died. On the 9th day, the rate of wound healing was observed to be fastest in a group of fish fed with 10g/kg *T. triangulare* (G_7) (82.2%), followed by G_5 (77.8%), G_3 (71.1%), G_6 (66.7%), G_4 (55.6%), and G_8 (44.9%) in that order, with the lowest value observed

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in G_1 (33.3%). By the 12th day, G_7 (95.6%) still maintained the highest rate of wound closure, followed by G_5 (84.4%) and G_3 (80.0%). The scar had finally dropped on fish in group G_7 (100%), while other groups still had scars but with varying degrees of wound closure by the 15th day. Figure 5 shows the epithelization of the wound in progress.

Figure 5. Showing the process of epithelization (arrowed).

It was observed that the more stressed fish (starvation and induced mild infection) showed less improvement in the rate of wound closure than the less stressed fish (starvation only), as shown in the pattern of the rate of wound healing (Table 3). The wound closure level up in all remaining fish by the end of the 23rd day of the trial.

Table 3. Pattern of the rate of wound closure in the experimental fish.

Days	Group of Experimental Fish
3	$G_5 > G_3 > G_6 > G_4 > G_7 > G_8 > G_1 > G_2$
6	$G_5 > G_3 > G_6 > G_4 > G_7 > G_8 > G_1$
9	$G_7 > G_5 > G_3 > G_6 > G_4 > G_88 > G_1$
12	$G_7 > G_5 > G_3 > G_6 > G_4 > G_8 > G_1$
15	$G_7 > G_5 > G_3 > G_8 > G_6 > G_4 > G_1$

The different levels of wound healing in different groups of fish fed with medicinal plants: and without pathogenic *P. aeruginosa* injection were compared as shown in Figure 6 for all the trial groups.

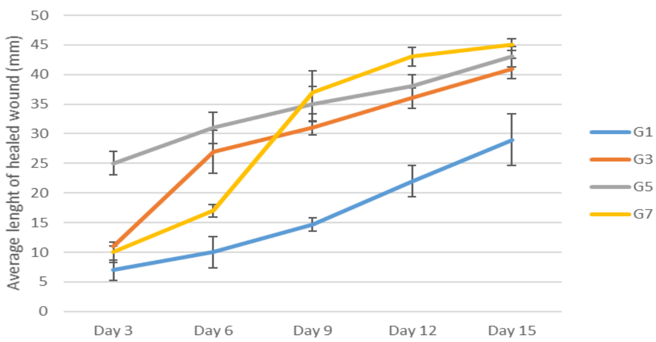

Figure 6. Different levels of wound healing in different groups of fish fed with medicinal plants: G_1 = Group fed without herbal diet and pathogenic *P. aeruginosa* injection (Negative Control); G_3, G_5, and G_7 = Group fed with 5.0g/kg *A. sativum,* 10.0g/kg *C. odorata* and 10.0g/kg *T. triangulare* respectively and without pathogenic *P. aeruginosa* injection.

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The different levels of wound healing in different groups of fish fed with medicinal plants: and with pathogenic *P. aeruginosa* injection were compared as shown in Figure 7 for all the trial groups.

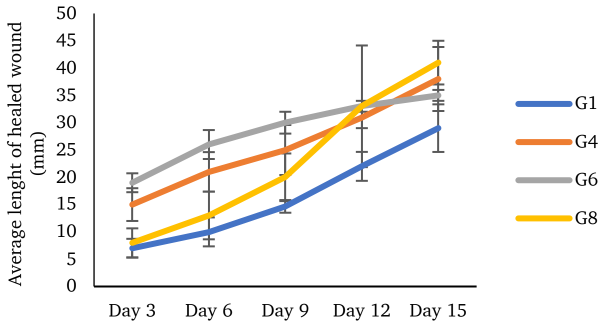

Figure 7. Different levels of wound healing in different groups of fish fed with medicinal plants: G_1 = Group fed without herbal diet and pathogenic *P. aeruginosa* injection (Negative Control); G_4, G_6, and G_8 = Group fed with 5.0g/kg *A. sativum,* 10.0g/kg *C. odorata* and 10.0g/kg *T. triangulare* respectively and with pathogenic *P. aeruginosa* injection.

Cannibalism is antagonistic behavior that can be caused by stress induced by various shared and environmental factors. This occurred in aquaculture as a result of injuries inflicted on the body, leading to the creation of a wound. This phenomenon is associated not only with a dramatic decline in fish survival but also with an increase in the number of infections (the result of body surface damage) and causes considerable economic losses. Trauma triggers the biological process of wound healing, which concludes with the development of scar tissue. The objectives of wound care include lowering the risk factors that prevent wound healing, accelerating healing, and limiting the likelihood of wound infection.

There is a lot of potential for managing and healing wounds with medicinal herbs. These organic substances encourage tissue regeneration and healing in diverse ways. The medicinal value of these plants is due to their bioactive components, which have distinct physiological effects on animal bodies. Given the significance of wound healing and the possibility that untreated open cutaneous wounds can result in local infections or even some malignancies, ongoing attempts have been made to improve wound healing. Lieke *et al.* (2020) noted that there aren't many very effective wound treatment options available in aquaculture. In this study, the use of medicinal plants as vital therapeutic agents for fish wound management, specifically as an alternative to antimicrobials or chemicals, was examined. Fish that had intentionally sustained wounds, fish that were starved, and some fish that were further stressed by being infected with low doses of pathogenic *P. aeruginosa* were all treated with three plants that had previously been known to have medicinal properties. Based on a macroscopic examination of the wound, the current study demonstrated a substantial difference in the healing pattern between the fish groups given herbal additives and the control groups, which became more obvious as of the sixth day.

Injuries are probably a part of life. It could be brought on by an injury to the skin that is chemical, physical, microbiological, etc. (Dário *et al.*, 2014). The process through which the skin or tissue is repaired after an injury is known as the wound-healing machinery (Martin and Nunan, 2015). In typical skin, the

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inner or profound layer and the peripheral layer epidermis coexist in an unfavorable equilibrium condition, forming a protective wall against the outside environment. When the defensive wall is compromised, the usual wound-healing process starts right away. The entire wound-healing process, which begins as soon as the injury occurs, may take days to years (Nagori and Solanki, 2011). A lack of protein can reduce the amount of collagen synthesis or raise the danger of contamination as a result of consuming unhealthful foods (Dupont *et al.*, 2013).

One of the three medicinal plants used in this investigation, *C. odorata*, exhibited the quickest start to the wound healing process. This shows that *C. odorata* might have hemolytic, immunostimulant, antioxidative, anti-inflammatory, and antibacterial effects, as described by Sermakkani and Thangapandian (2021). By decreasing whole blood clotting time, which is a crucial pointer of the hemostatic effect, *C. odorata* extracts stopped bleeding from fresh wounds (Paul *et al.*, 2018). According to Pandith *et al*. (2012), *C. odorata* leaf extracts decreased the blood's clotting time, which suggests that they may also slow the blood clotting pathways. The presence of tannins and saponins in the herbs is thought to be responsible for their hemostatic action, supporting the traditional use of the *C. odorata* leaf in wound healing (Zachariades *et al*., 2009). The current study's findings provide pharmacological support for the traditional usage of fresh *C. odorata* leaves to treat wounds.

In this study, garlic (*A. sativum*) also demonstrated great potential for wound healing since it prevented the degeneration of the wound when fed to specific groups of fish as feed additives. According to Choudhary *et al*. (2022), *A. sativum's* pharmacological effects include anti-coagulant, anti-inflammatory, and wound-healing actions. These effects require greater attention from scientists. This research demonstrated how well garlic works to heal wounds and has anticoagulant, anti-inflammatory, and immunomodulatory properties in African catfish.

Although *T. triangulare*'s assistance in the healing processes was not as fast as the other two at the beginning, it eventually healed faster than the other two plants examined. Waterleaf demonstrated a fantastic improvement in wound healing compared with the other two medicinal plants evaluated. This finding could be explained by the fact that *T. triangulare*, as reported by Ezekwe *et al*. (2013) considerably increased RBC concentration in mice. A study by Tiamiyu *et al*. (2019) that found that African catfish juveniles fed a diet fortified with *T. triangulare* additives had enhanced blood quality contributed to this observation as well. According to prior research reported by Airaodion *et al*. (2019), water leaf can be used therapeutically to treat cardiovascular diseases like obesity and stroke. It is also occasionally used as a mild sweetener for other plant species. The potential of nutraceuticals in the treatment of wounds in aquaculture has been made clear by this study. Garden-fresh raw materials from medicinal plants were employed to create synthetic medications (Dawid-Pac, 2013).

Phytochemicals, which are naturally found in plants, exploit dietary fibers and nutrients to protect animals and people from illnesses (Boudjeko *et al*., 2015). Nigeria is abundant in valuable medicinal plants, and many of them have been documented. However, due to a lack of appropriate study, many plants are underutilized, especially outside of the traditional neighborhoods where they are grown and consumed. This discovery will arouse scientists' interest in additional investigation into the health advantages of medicinal plants and the conditions for which they are used to create viable treatments for some common disorders.

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CONCLUSION

From the perspective of production, it is crucial to prevent fish injuries due to consequences for the end product's quality as well as considerations for the welfare of the fish. Establish baseline data for upcoming investigations into *C. gariepinus* wound healing. The current study also offers some useful data on the effectiveness of medicinal herbs for treating wounds in farmed fish. It has been shown that dietary inclusion of *A. sativum*, *C. odorata*, and *T. triangulare* separately at lower inclusion rates of 0.5 percent to 1.0 percent improves fish wound healing processes and prevents contamination of wounds, and this could reduce death that might occur as a result of physical attack among the cultured fish. It also suggests that the cultured organism's ability to withstand stress is improving.

CONFLICT OF INTEREST

The authors state that no commercial or financial ties that may be considered as a possible conflict of interest were present throughout the research.

AUTHOR CONTRIBUTION

Adebisi Musefiu Tiamiyu: conceived and designed the experiments, performed the experiments; analyzed, and wrote the paper. Folusho B. Bolaji-Alabi: validation, writing-reviewing, and editing. Reuben Chukwuka Okocha: analyzed and interpreted the data, reviewing and editing. Isaac Olufemi Olatoye: data curation, reviewing, and editing. Oluwafemi Bolarinwa Adedeji: contributed reagents, reviewing, and editing.

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