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Optimisation of Some Conditions for the Biodegradation of Low-Density Polyethylene Strips by Fungi Isolated from Parts of North Central Nigeria

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Abstract: Some optimum conditions (Incubation time, pH and Temperature) were studied for selected fungal isolates – Aspergillus flavus, Aspergillus niger, Fusarium chlamydosporium, Trichoderma sp. Mucour indicus, Rhizopus miehei, Basidobolus ranarum, and Microsporum nanum, to biodegrade low-density polyethylene (LDPE) waste by using Mineral Salts Medium (MSM) containing 0.500g LDPE strips (1cm by 5cm each) using changes in pH of the media and weight loss of the strips as indicators for ability of these microorganisms to degrade LDPE. The results revealed that four of the eight fungal isolates, Aspergillus flavus, Aspergillus niger, Fusarium chlamydosporium and Trichoderma sp. showed high ability to degrade the LDPE strips after 8 weeks of incubation in Mineral Salts Medium at pH7.05 and 30°C. There was noticeable variation in pH of the media with time of incubation with the highest change recorded for Aspergillus flavus (3.00±0.01), Aspergillus niger (3.02±0.01) and Rhizopus miehei (3.10±0.01) when compared with the control (without fungi) which remained at PH 7.05±0.02 during the 8-week incubation period. The weight loss of the LDPE recorded for Aspergillus flavus was 19.40±0.14 %, Aspergillus niger 19.40±0.18%, Fusarium chlamydosporium, 12.60±0.10% and 10.60±0.02% for Trichoderma sp. respectively. The weight loss of the LDPE strips was time dependent with the highest weight loss recorded after 8 weeks for all isolates. The optimum pH of 7.5 was recorded for LDPE degradation by Aspergillus flavus, Aspergillus niger, Fusarium chlamydosporium and Basidobolus ranarum while optimum pH of 6.5 was recorded for Trichoderma sp., Mucour indicus, Rhizopus miehei and Microsporum nanum. All the fungal isolates showed optimum LDPE degradation activity at 34°C except Fusarium chlamydosporium, Trichoderma sp., Mucour indicus and Rhizopus miehei which optimized activity at 32°C.

Keywords: LDPE Biodegradation, Optimum conditions, Fungi and Weight Loss.

I. Introduction

Low-Density Polyethylene (LDPE) wastes are the most common type of plastic wastes in the environment. This is because LDPE constitutes about 60% of all plastics produced [1] and consumed due to its unique properties of flexibility, durability, strength, inertness and light-weight; thus it is the most commonly found solid waste [2,3]. They are used particularly in the packaging industry as carrier and garbage bags, as well as in the production of electrical and agricultural materials.

Plastic and other solid waste disposal systems in Nigeria, like most developing countries are poor, inefficient, and largely uncontrolled [4]. Currently, solid waste management is one of the most pressing environmental challenge faced by urban and rural areas in Nigeria [5]. Disposal involves indiscriminate dumping in open spaces or make shift landfills, and waterways. They are unsightly, block urban drainage systems and sewers, causing flash floods as well as providing a fertile ground for breeding mosquitoes and other water borne-diseases [6].

LDPE wastes are often seen burning openly or incinerated uncontrollably, releasing dangerous Persistent Organic Pollutants (POP) such as dioxins and furans into the environment which pose lots of health hazards to the populace [8].

Using landfills for disposal is not encouraged because it takes up more land spaces than communities can afford due to urgent needs for valuable infrastructure like hospitals and schools, hence this is relegated and rarely considered. Landfills also constitute environmental nuisance because LDPE's hydrophobic nature and high molecular weight makes them recalcitrant and not easily degraded under natural conditions [9].

Increasing accumulation of polyethylene plastics in the environment has become a worldwide problem and severe threat to the planet [1].

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Biodegradation is the most ecofriendly alternative to dispose LDPE wastes; the process is cheaper and the secondary products can be of economic value in comparison to conventional methods such as incineration [10, 11]. It involves the use of microorganisms usually bacteria and fungi to break down (degrade) the plastic polymer. Several studies have reported the biodegradation of polyethylene by bacterial (Kathiresan, 2003; Sivan *et al.,* 2006), fungal species [12, 13]. well as algae [14, 11].

Fungi have been reported to be good degraders of polyethylene; their rapid growth and extensive mycelium, cause them to spread out to cover the entire substrate surfaces, penetrating them to start the biodegradation process [15]. Fungi are ubiquitous, they can be found in many kinds of environments such as low pH and arid [16]. Indigenous fungi from plastic polluted landfills and dumpsites have been variously reported as potential agents of plastic biodegradation[7], however the exact mechanisms and conditions to maximize their activities especially under laboratory conditions are not fully understood.

It is therefore the aim of this study to optimize some of the conditions necessary for biodegradation to increase the ability of indigenous fungi to degrade low-density polyethylene.

II. Materials and Methods

Chemicals and Reagents*:*

Malt extract Agar (MEA) for the isolation of fungi consisted of**:** Glucose 10g/l, Malt Extract 10g/l, Peptone 2g/l, Asparagine 1g/l K_2HPO_4 2g/l**,** $MgSO_4.7H_2O$ 1g/l, Thiamine – HCl 0.001g/l.

Mineral salt Media content:

In one liter of deionized water: K_2HPO_4, 0.5g, KH_2PO_4, 0.04g, NaCl, 0.1g, $CaCl_2.2H_2O$, 0.002g, $(NH_4)_2SO_4$, 0.2g, $MgSO_4.7H_2O$, 0.02g, $FeSO_4$, 0.001g, Agar, (optional), 20.0 g, pH 7.0 ± 0.2.

Nutrient Basal Media:

The basal salts mineral media used contained the following elements (prepared in distilled water): 12.5g/l K_2HPO_4; 3.8/l KH_2PO_4; 1.0g/l $(NH_4)2SO_4$; 0.1g/l $MgSO_4.7H_2O$ and 5ml trace element solution contain each of the following elements (prepared in distilled water): 0.232g/l H_3BO_3;0.174g/l,$ZnSO_4.7H_2O$;0.116g/l$FeSO_4(NH_4)$ $2SO_4.6H_2O$;0.096g/lCoSO4.7H2O;0.022g/ l(NH_4) $6Mo7O_2.4H_2O$; 8.0mg/lCuSO4.5H2O; 8.0mg/l$MnSO_4.4H_2O$.

Description of the Study Area

The North Central geopolitical zone of Nigeria also called the Middle belt, consists of six states namely, Benue, Kogi, Kwara, Nasarawa, Niger, Plateau and the Federal Capital Territory (F.C.T), Abuja and the environs. This is a major division in Nigeria created during the regime of the former head of state, Ibrahim Badamasi Babangida for easy management and allocation of resources. The major towns (Capital cities) are Abuja, Minna, Lokoja, Jos, Makurdi, Lafia and Illorin. It is from these seven major towns that the four parts focused in this study were randomly drawn. Hence, Abuja, Markurdi, Lafia and Jos were drawn.

Sample collection

Garbage soil samples from waste disposal (dump) sites were collected using the method of Anbuselvi, [17]. Soil samples were collected from three biggest garbage dump sites in each of the four cities under study. Soil sample were collected from top 10cm of the soil profile using a sterile spatula and placed in sterile sample bags and clearly labeled. Waste LDPE polyethylene films (clear), from each site was also collected in separate sample bags, labelled and transported to the laboratory.

Isolation of fungi

The fungi species were isolated using a method described Makut *et al.* [18]. Ten grams (10 g) of the soil was suspended in 90ml of sterile distilled water and 10-fold dilutions was made. 1ml of the soil suspended (the stock) was pick using petite and transferred into first test tube containing 9ml of sterile water another 1ml of water was pick from the first test tube using petite and transferred into second test tube containing 9ml of sterile water this step was performed till 10 times and 0.3 ml of the aliquot was pick from 5th tube and spread on potato dextrose agar incubated at 26 °C for 4 days. Growth colonies were sub-cultured again on potato dextrose agar and later stored in slants for further use.

Identification of fungi species

Identification of fungi was carried out by the method adopted by Makut *et al.* [18]. The cultural characteristics of fungi were determined by their growth appearance on culture plates and the morphological features were determined microscopically using lactophenol cotton blue staining technique, where lactophenol cotton blue strain was dropped on a clean grease free microscope slide, a small portion of mycelium or colony from the fungi culture plate was dropped on the lactophenol cotton blue with aid of mounted needle, the mycelium was spread well with the two mounted needle and covered with cover slip. The slide was then viewed under the microscope at x40 and x100 lens. The images were identified with reference to the work of [9] and fungi standard chart atlas.

Waste Polyethylene Bag Preparation and Culture Condition

A method described by Kyaw & Champak [19] was used in preparing waste polyethylene. Polyethylene films were collected from three sites randomly selected from dump sites in each of the four capital cities chosen for this study in North Central Nigeria. These were cut into (5cm X 1cm) strips and then washed first with tap water to remove all debris and soil particles. Then, they were washed with 70% ethanol for 30 minutes, washed with distilled water and subsequently dried in incubator at 60ºC before exposure to the fungal isolates. Inoculation and incubation were carried out under aseptic conditions.

Fungal Inoculation / Biodegradation Measurement

pH Changes

Using falcon tubes, 30ml of the basal mineral medium and 600µl of the fungal stock about 24 days old was mixed with 0.500g of the polyethylene strips [20,21]. The initial concentration of the fungal isolates was at 0.5 McFarland Standard. The tubes were incubated at 30ºC, and lid was slightly opened for aeration [19]. The tests were performed in triplicate for each isolate.

Using the methods of Arutchielvi, [22], the pH of the basal mineral media inoculated with fungal isolates were monitored using a pH meter at 2, 4, 6, and 8 weeks' incubation to ascertain microbial activity and biodegradation of the LDPE strips. There was a set of control experiments in the test tubes containing only the LDPE strips films in basal nutrient medium.

Weight Loss method

The LDPE strips after exposure to each of the fungal isolates were evaluated for weight loss using the methods of Hadad *et al*., [23]and Kyaw and Champakalakshmi [19] after eight weeks of incubation. The strips were collected and then washed thoroughly with 2% (v/v) aqueous Sodium Dodecyl Sulphate (SDS) solution for 4 hours. They were dried at 60ºC overnight in an incubator and placed on a filter paper before weighing with a microbalance; the percentage weight loss was determined using the following formula:

Weight loss (%) = initial weight – final weight/initial weight X 100.

There was a set of control experiments in the test tubes containing only the LDPE strips in basal nutrient medium devoid of any microbial inoculum.

Determination of the Optimum Conditions for Biodegradation of LDPE strips by fungal Isolates

Effect of incubation Time

To determine the effect of incubation time on the ability of the fungal isolates to degrade LDPE, Basal Salt Medium of pH 7.05 supplemented with 0.1% PE was inoculated with each of the isolates and incubated at different times, 2, 4, 6, 8 weeks [24]. Biodegradation was measured gravimetrically as percentage weight loss of the LDPE strips [23].

Effect of pH

The effect of pH on the ability of the predominant fungal Isolates to utilize LDPE as a sole source of carbon and nitrogen was determined using the method of Al- Jailawi *et al*., 2015. Using a supplemented basal salt medium (MSM) with 0.1% LDPE adjusted to different pH values (4.5,5.5, 6.5, 7.5 and 8.5) using a phosphate buffer [3] to determine the optimum pH for biodegradation activity. The culture was incubated in a shaker incubator (180rpm) at 30ºC for 8 weeks. The optimum pH was employed in subsequent experiment.

Effect of Temperature

To determine the effect of temperature on the ability of the fungal isolates to degrade LDPE, basal salt medium (with optimum pH from 2.9.2) supplemented with 0.1% LDPE was inoculated with each of the isolates and incubated at different temperatures (28 ºC, 30 ºC, 32 ºC, 34 ºC, and 36ºC) for 8 weeks according to the method of Al-Jailawi *et al.,* [25]. Biodegradation was measured gravimetrically as percentage weight loss of the LDPE strips. Optimal temperature obtained for each of the isolates was subsequently employed, depending on the growth density measurement.

Data Analysis

All analysis was conducted in triplicate and analyzed using Microsoft Excel Windows 10 program and Smith Statistical Package (SSP) version 3.1, with significance determined at 95% confidence level. Results are presented as means ± standard error of the mean.

III. Results

Biodegradation measurement - Changes pH of the Mineral Salts Medium

The PH of the mineral salt media containing LDPE strips and fungal isolates are as shown in table 3.1 and figure 3.1 below. The changes in the pH of the media, originally set at 7.05±0.02) showed a reduction in pH for all the fungal isolates ranging from 3.00±0.01 to 4.10±0.01 after eight weeks' incubation. The highest reduction in pH was observed for *Aspergillus flavus*

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(3.00+0.01) and *Aspergillus niger* (3.02±0.01) followed by *Fusarium chlamydosporium* (3.35±0.01) when compared with the control (7.05±0.02) which remained the same for the incubation period.

Table 3.1: Changes in pH of Media over Time of Incubation with Fungal Isolates

Fungi	**Initial**	**pH recorded over time (weeks)**			
		2	**4**	**6**	**8**
Control	7.05±0.02	7.05±0.02	7.05±0.02	7.05±0.02	7.05±0.02
Aspergillus flavus	7.05±0.02	5.00±0.02	4.61±0.05	3.85±0.02	3.00±0.01
Aspergillus niger	7.05±0.02	5.02±0.02	4.15±0.05	3.91±0.02	3.02±0.01
Fusarium chlamydosporium	7.05±0.02	5.11±0.01	4.81±0.05	4.01±0.02	3.35±0.01
Trichoderma species	7.05±0.02	5.05±0.02	4.85±0.05	4.05±0.02	3.48±0.01
Muc Mucor indicus	7.05±0.02	5.25±0.01	4.90±0.05	4.50±0.02	3.25±0.01
Rhizopus miehei	7.05±0.02	5.35±0.02	5.01±0.05	4.35±0.02	3.10±0.01
Basidobolus ranarum	7.05±0.02	6.85±0.01	5.75±0.03	4.85±0.01	4.00±0.02
Microsporum nanum	7.05±0.02	6.40±0.02	5.05±0.05	4.51±0.02	4.10±0.01

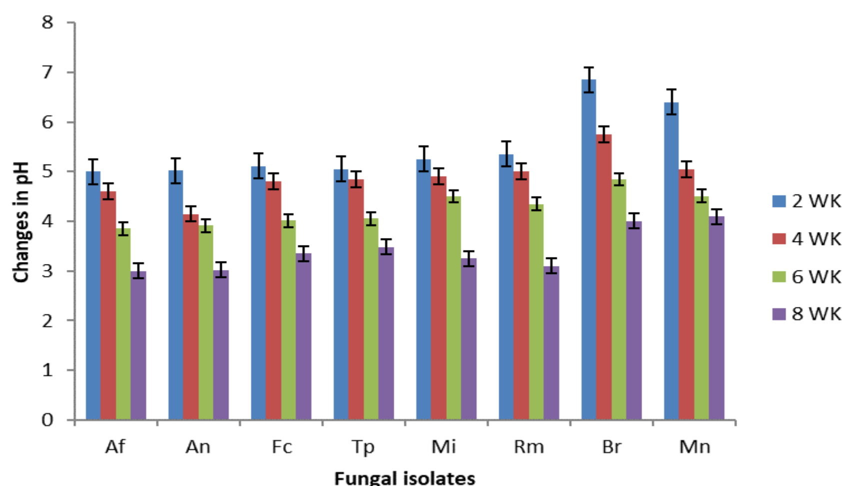

Figure 3.1 Changes in pH of media over time of incubation with fungal isolates

Biodegradation – Weight loss of LDPE strips over time of Incubation.

The percentage weight reduction of the LDPE strips increased over time for all the fungal isolates as shown in Table 3.2. The highest weight reduction was recorded after 8 weeks' incubation for *Aspergillus niger* and *Aspergillus flavus* (19.40±0.18% and 19.40±o.14%) respectively, but lowest after 8 week incubation for *Mucour indicus* (8.60±0.11%) and *Rhizopus miehei* (5.80±0.31%) respectively as shown in Figure 3.2. There was no weight reduction recorded for the LDPE waste strips in the control experiment.

Table 3.2 Effect of Duration of Incubation on the Biodegradation of LDPE Wastes by Fungal Isolates

Fungi	**Initial weight of LDPE strip(g)**	**Percentage weight loss of LDPE films over time (weeks) (%) 2**	**4**	**6**	**8**
Control	0.500	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Aspergillus flavus	0.500	3.40±0.08	5.40±0.41	14.20±0.19	19.40±0.14
Aspergillus niger	0.500	4.20±0.12	7.20±0.10	14.20±0.01	19.40±0.18
Fusarium chlamydosporium	0.500	6.00±0.10	7.00±0.21	11.20±0.28	12.60±0.10
Trichoderma sp.	0.500	4.60±0.17	6.80±0.01	10.80±0.01	10.60±0.02
Mucor indcus	0.500	5.40±0.19	6.20±0.12	6.60±0.18	8.60±0.11
Rhizopus miehei	0.500	3.60±0.21	5.40±0.01	5.60±0.11	5.80±0.31
Basidobolus ranarum	0.500	3.40±0.07	4.40±0.17	5.00±0.19	5.20±0.05
Microsporum nanum	0.500	4.00±0.03	5.20±0.09	5.20±0.10	6.00±0.08

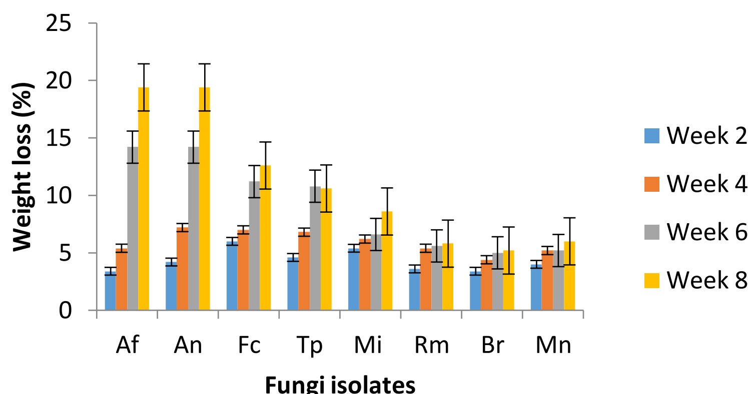

Figure 3.2: Percentage weight loss of waste LDPE films by Fungi isolated from dump sites in parts of North Central Nigeria in relation to duration of incubation in weeks.

Effect of pH on Biodegradation of Low Density Polyethylene (LDPE) Strips

The percentage weight reductions of the LDPE strips over 8 weeks' incubation period is as shown in table 3.3. The percentage weight loss recorded for the LDPE strips ranged between 22.20±0.19-38.20±0.14% at pH changes between 4.5-8.5. The highest percentage weight loss was recorded at pH 7.5 for *Aspergillus flavus* (38.20±0.14%) and *Fusarium chlamydosporium* (22.20±0.19%) but remarkably low at pH 4.5 for *Microsporum nanum* (2.20±0.00%), *Trichoderma* sp. (3.00±0.01%) and *Aspergillus. niger* (3.80±0.00%) respectively as shown in Figure 3.3.

Table 3.3 Effect of pH on Waste LDPE Biodegradation using Fungi Isolates

Fungi		**Percentage weight loss in pH (g/g)**				
	Initial weight(g/g)	**4.5**	**5.5**	**6.5**	**7.5**	**8.5**
Control	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Aspergillus flavus	0.500	4.20±0.01	9.40±0.10	13.60±0.11	38.20±0.14	14.20±0.01
Aspergillus niger	0.500	3.80±0.00	10.40±0.06	16.00±0.08	16.40±0.11	12.60±0.21
Fusarium chlanydesporium	0.500	6.20±0.02	9.60±0.01	20.40±0.06	22.20±0.19	17.40±0.04
Trichoderma sp.	0.500	3.00±0.01	6.60±0.04	14.40±0.02	12.20±0.03	8.20±0.00
Mucor indcus	0.500	8.60±0.00	9.20±0.01	14.20±0.11	12.60±0.01	8.20±0.03
Rhizopus miehei	0.500	4.20±0.01	13.00±0.00	13.40±0.05	11.40±0.00	9.80±0.04
Basidobolus ranarum	0.500	6.80±0.04	7.80±0.00	8.00±0.00	8.20±0.08	6.20±0.00
Microsporum nanum	0.500	2.20±0.00	4.80±0.00	7.40±0.04	7.40±0.00	6.40±0.07

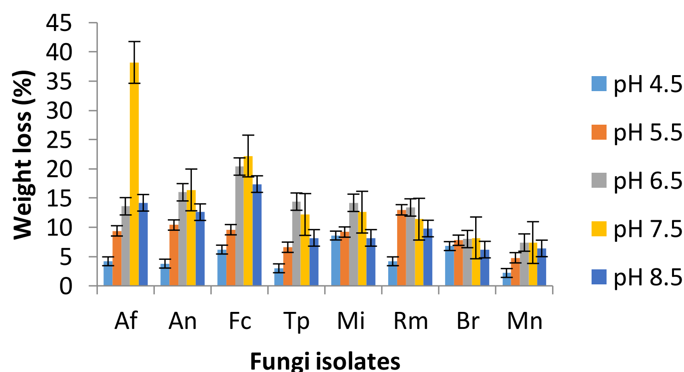

Figure 3.3 Percentage Weight loss of waste LDPE films by fungi isolated from dump sites in parts of North Central Nigeria in relation to pH.

Effect of Temperature on Biodegradation of Low Density Polyethylene (LDPE) Waste

The effect of temperature on biodegradation of LDPE strips by fungi isolated from the soil from dumpsites in parts of North Central Nigeria is as shown in tables 3.4 and figure 3.4 respectively.

The percentage weight reduction of LDPE strips at temperature of exposure between 28ºC – 36ºC were within the range of 0.0-56.2% and the highest percentage weight reduction of LDPE strips for *Aspergillus flavus* was obtained at 32 ºC and 34ºC with percentage weight reduction of 53.2±0.11% and 56.2±0.04% respectively, while *Aspergillus niger* biodegradtion activity optimised at 34ºC with percentage weight reduction of LDPE strips of 52.4±0.11% while *Basidobolus ranarum* had the lowest percentage weight reduction of LDPE strips with percentage weight reduction ranging from 0.0-8.2% respectively as shown in Figure 3.4. The percentage weight reduction was lowest at 36ºC for all fungal isolates.

Table 3.4 Effect of Temperature on the Biodegradation of LDPE Wastes by Fungi Isolates

Fungi		**Percentage weight loss at different temperatures ⁰C (%)**				
	Initial weight (g)	**28⁰C**	**30⁰C**	**32⁰C**	**34⁰C**	**36⁰C**
Control	0.500	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Aspergillus flavus	0.500	0.00±0.00	42.0±0.30	53.2±0.11	56.2±0.04	22.2±0.31
Aspergillus niger	0.500	6.0±0.11	33.4±0.16	40.0±0.08	52.4±0.11	20.0±0.21
Fusarium chlanydesporium	0.500	8.2±0.12	33.6±0.41	40.0±0.16	32.2±0.15	25.4±0.14
Trichoderma sp.	0.500	5.0±0.81	24.6±0.31	44.4±0.09	24.2±0.13	16.2±0.24
Mucor indcus	0.500	2.6±0.02	20.0±0.01	32.2±0.11	24.4±0.21	14.2±0.03
Rhizopus miehei	0.500	2.2±0.01	12.2±0.00	16.8±0.01	15.4±0.00	16.2±0.04
Basidobolus ranarum	0.500	0.00±0.00	0.00±0.0	4.0±0.03	8.2±0.00	6.2±0.00
Microsporum nanum	0.500	6.8±0.03	16.6±0.07	21.8±0.00	30.8±0.09	14.8±0.00

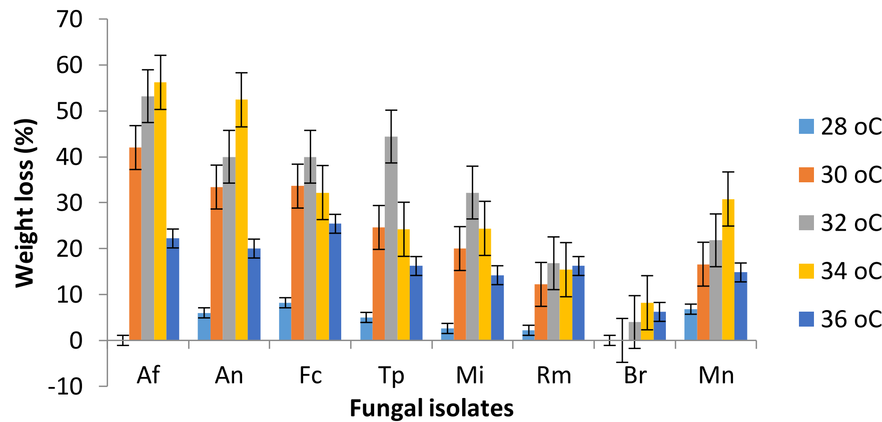

Figure 3.4 Percentage Weight loss of waste LDPE films by fungi isolated from dump sites in parts of North Central Nigeria in relation to temperature.

IV. Discussion

Some conditions required for the degradation of waste low- density polyethylene strips by the isolated microorganisms were monitored to determine optimal conditions for effective biodegradation. pH, temperature and incubation time were studied for all the fungal isolates. The results obtained are similar to the findings of Al-Jawali *et al.*, [25] that revealed that pH 6.5 was suitable for the growth of *Psuedomonas putida* in a mineral salts medium containing 0.5% LDPE although this is slightly lower than the optimum pH of 7.5 recorded for *Psuedomona*s species in this study. Hima *et al.*, [26], reported that the optimum pH required to degrade LDPE was pH 8.0 by *Alcaligenes sp and Methylobacillus sp.*; this is slightly higher than the results obtained from this study for all the fungal isolates.

The highest fungal degradation activity was recorded at pH 7.5 for *Aspergillus flavus* (38.20±0.14%) and *Fusarium chlamydosporium* at 22.2±0.19% but pH 6.5 was the optimum pH for *Trichoderma* sp. *Mucor indicus, Rhizopus meihei* and *Basidopolus rananum* degradation activities. Ali *et al*., [27] found no significant difference between LDPE degradation by *Fusarium equisetti* at pH 5 and pH 7 but pH 5 was chosen to optimize the weight loss in LDPE film percentage by *F.equiseti*. In this study 7.5 was found to be the optimum pH for LDPE degradation for most of the fungal isolates.

The duration of incubation is also an important condition that affects biodegradation processes. Results obtained in this study showed significant increase in LDPE degradation with time of incubation by the fungal isolates. This is in line with previous studies by Hussein *et al*., [28], Das and Kumar, [3] and Abdel-Shafy *et al*., [24] for LDPE degradation measured in terms of carbon dioxide evolution and LDPE weight loss as in this study. These results show that the hydrophobic nature of LDPE plastic polymer makes it recalcitrant in nature; for LDPE to yield to biodegradation, under the right environmental conditions, time is required for the microbes to grow and form biofilms on the surface of the polymer. This helps them to attach to the polymer

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surface and release extracellular enzymes on the polymer [18]. Time is also required for these enzymes to permeate the polymer surface and gradually erode the surface often with the formation of pits and holes that eventually disintegrates the polymer causing degradation [29]. It is expected that the longer the period of incubation, the greater the chances of biodegradation of the LDPE polymer.

The gradual increase in temperature form 28ºC to 36ºC (Table 3.4 and Figure 3.4) had remarkable effect on the fungal isolates. There was a remarkable LDPE weight reduction at slightly higher temperatures. The highest activity was recorded at 34 ºC by *Aspergillus* species recording 56.2±0.04% LDPE weight loss by A. *flavus* and 52.4±0.11% weight loss by *A.niger*. However, at 32 ºC, *Trichoderma* sp. and *Fusarium chlamydosporium* gave their highest degradation activity at 44.44±0.09% and 40.0±0.16% LDPE weight loss respectively. 32 ºC is taken as the optimum temperature for LDPE degradation for most of the fungi isolated in this study.

There was also a general decline in activity for all fungal isolates with increasing temperature. This gradual decrease in fungal growth and in LDPE utilization activity with increasing temperature may be attributed to the accumulation of metabolites resulting from oxidation processes produced by microbial isolates, or to a lack of oxygen and nutrients as suggested by Bishnoil *et al*., [30]. It could also be due to denaturation of some of the extracellular enzymes responsible for degradation activity [18]. This is different from results obtained by Kumari *et al*., [6], which reported enhanced polyethylene biodegradation at higher temperatures of 40ºC with LDPE weight reductions between 24 – 28% compared to results obtained in this study.

V. Conclusion

This study indicates that naturally growing soil fungi from dump sites in the capital cities of some states in north central Nigeria show great capacity to utilize low-density polyethylene at different degrees. The optimum conditions assessed in this study showed that, the fungal isolates were able to degrade low-density polyethylene at pH 7.5 and temperature of about 32ºC after 8 weeks of incubation. It also shows that it is possible to improve the degradation capacity of these isolates such that the concept of biodegradation elucidated in this study can be applied on a commercial scale.

Further molecular studies are required to determine the catabolic genes resident in these fungal isolates which are responsible for their ability to utilize LDPE as well as examine other environmental conditions that could be optimized to enhance fungal degradation of low-density polyethylene.

Conflict of Interest: The author declared no conflict of interest exist.

Ethical Approval: Not Applicable

Authors Contributions: This study was conducted in collaboration of all authors. All authors read and approved the final version of the manuscript.

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