Original Research Article

Effect of processed feather waste as mulch on crop growth and soil fertilization

Abstract

Management of waste feathers in Nigeria is of public health concern due to large quantities generated daily from poultry industries and slow degradation in soil. Information on processing waste feathers for enhancing crop growth has not been well documented, particularly in Nigeria. This study assessed the effect of processed waste feathers on crop growth and soil fertilization in order to provide a cheap and sustainable source of organic fertilizer for use.

The study design was experimental and laboratory based, using maize as test crop. Waste chicken feathers were washed, air-dried, ground into bits, and analyzed for nitrogen, phosphorus and potassium contents. Eighty grams feather-bits were mixed with 27g of glycerol plasticiser at 65^0C to obtain a paste and then pressed for ten minutes into flattened organic mulch. Eight 14cm-diameter pots of 1.5 liters capacity were obtained and divided into two groups(A and B) of four replicates each in a completely randomized design. Maize seeds were planted in 1 kg sieved soil in the pots. Surfaces of the soil in the experimental group B was covered with feather mulch while control group A was without mulch. All pots were sprinkled with water daily to water holding capacity. Length of leaves and shoots of crop were measured at intervals for 28 days using flexible measuring tape. Data were analysed using descriptive statistics and student t-test.

About 4980 kg of feathers are generated daily from 30000 chickens from two industries (0.166 kg or 8.52% by mass per chicken). Feathers contained 14.1% nitrogen, 0.2% phosphorus and 0.6% potassium. Mean length of shoots in group B (mulched) showed significant increase (P= 0.01) on day 8 at 3.3 ±0.1cm against 3.1 ±0.1cm for control group A, while mean length of maize leaves showed significant increase (P= 0.05) on day 20 at 27.8 ±2.2 cm over control at 25.6 ±1.6 cm. The mulch increased growth of maize shoot and leaves significantly by 6.5% and 8.6% respectively.

It is concluded that organic mulch made from processed waste feathers was effective on crop growth and soil fertilization and it can be a useful strategy for poultry waste management.

Key words: Waste feathers, feather mulch, soil fertilization, plasticizer, keratin.

Introduction

The burden of solid waste management is of particular concern in many cities of the world due to rural-urban migration and globalization. In Nigeria, solid waste generation has been on the increase. Nigerian cities produce large quantities of waste at the rate of 0.43 kg - 0.52 kg per capita per day [1]. Cities like Lagos and Ibadan generate almost 0.5 kg waste/capita/day while the national average was 0.45 kg waste/capita/day [2]. While attempts are being made to reduce, reuse and recycle theses wastes, the enormity of waste feathers generated still constitute nuisance to the environment. This has attracted attention to researchers in the past to attempt a sustainable waste management technique for the feathers. The poultry industry is on the increase and the contribution of feather waste to the total waste is substantial, as there is a rise in the consumption of chickens all over the world. In the United States alone, more than 8 billion broiler chickens are produced yearly [3]. In the United States, the poultry industry discards 2 million tones of chicken feathers as waste annually [4][5]. In Nigeria, poultry form major sources of cheap animal protein for the growing populations. It is also a main food item served at various celebrations. In Ibadan, two poultry industries located in Oluyole Estate slaughter over 30,000 chickens per day and the feather waste is disposed off indiscriminately [5][6].

Some of the waste also goes into landfills and remain longer periods undegraded. The use of waste feathers for making organic mulch has not been well documented in Nigeria. Hence this study intends to identify a more economically sustainable method of handling waste feathers by converting the resource into a product which will release the much needed nutrients into the soil. This will ultimately increase crop yield and reduce the cost of food production, thereby promoting food security to meet the Millennium Development Goals (MDG).

Feathers are the covering of poultry and birds. Poultry feathers form between 6-9% of the total weight of a chicken and are composed of about 91% protein, 8% water and 1% lipids [7]. The type of protein in feathers is called keratin, a sulfur containing fibrous protein. All keratins are characterized by a high level of the sulphur-containing di-amino acid cystine,

which acts as a cross-linking point between protein chains [8][9]. This feature of a high-level of interchain cross linking through cystine gives the keratins, especially the hard keratin, their characteristics of toughness, durability, resistance to degradation, and desirable mechanical properties [10][11].

Waste feathers can be transformed into useful materials [12][13] such as protein-based mulching films which are not yet in use in Nigeria. Other available mulching methods include polyethylene mulching films, use of compost, and stone and grass clippings. Plastic mulch can provide earlier crop maturity, higher yields, increased quality, improved disease and insect resistance, and more efficient water and fertilizer use, but carries a high cost financially and environmentally when it comes to removing the estimated one million tons of mulch film used internationally each year [14][15][16] carried out a study comparing black and white biodegradable mulch films in two thicknesses to traditional plastic mulch in the production of tomato. The results of the study showed that lowest soil temperatures were identified with the white films, which is also associated with the white film's higher rate of degradation. However, unlike polyethylene mulching films which need to be collected at the end of the growing season due to their non-degradability, the protein-based films will slowly degrade into the soil within six months to one year before the next planting season. As soon as water exchanges with the plasticizer in the protein mulch, the films will be embrittled and will begin to crack under environmental stress such as wind, rain, and microbial activities and begin to degrade. The slightly high cost of the protein-based films is more than offset by the lack of labour costs to collect it from the field after the planting season, thus making it highly competitive with other prevailing methods of mulching. Therefore, this study is aimed at processing waste feathers into useful mulch for the purpose of enhancing crop growth.

Methodology

The study was experimental and was conducted in a greenhouse using a completely randomised design. It was carried out in the Institute of Agricultural Research & Training (IAR&T), Apata, Ibadan. Maize was used as the test crop. DMR-ESR-Y (Downey Mildew Resistance – Early Streak Resistance – Yellow) strain of maize was purchased from the grain store of IAR&T. Waste feathers were collected from Zartech Industries at Oluyole Industrial Estate, Ibadan. The company was registered in Nigeria in 1983 as an agricultural production establishment and has several units of poultry processing.

Large quantity of humus (top) soil sample was collected from the arable field of Institute of Agricultural Research and Training (IAR&T). The soil sample collected was sieved through a 3 mm pore-sized sieve to remove debris and allow easy penetration of seedling shoots and roots in the soil. Chemical analyses were carried out on the soil samples using standard methods described by AOAC [17] to determine its nutrient status, viz. organic carbon, Total Kjeldahl Nitrogen (TKN), potassium and phosphorus.

Eight plastic pots with capacity of 1.5 litres were obtained and divided into two groups of four replicates each. The pots had diameter of 14 cm. Three kg of treated soil was measured into each pot. The soil measured a depth of about 11.5 cm inside each pot. The pots were labeled and seeds were planted as follows:

i. Group A pots were labeled as Maize without mulch to serve as the control group
ii. Group B pots were labeled as Maize with mulch application to serve as the test group

Four seeds of maize were planted in each pot and the seedlings were thinned to two stands per pot after germination. This is to allow only healthy seedlings to grow and to avoid overcrowding. Chemical analysis was carried out on the waste feathers to determine the amounts of various nutrients present, particularly nitrogen, phosphorus and potassium.

Proportion of feather to whole chicken

It was difficult to determine the percentage by weight of feathers in the whole bird because the feathers are quite light and fluffy and as a result, not easy to be completely collected together and weighed dry. Hence the average percentage by weight of feathers in each bird was determined by comparing the weights of live chickens, dead chickens (drained of blood) and completely de-feathered chickens. The formulae used are as follows:

Live Weight (LW) = weight of each live bird

Dead Weight (DW) = weight of each dead bird after completely drained of blood

Weight of De-feathered Bird (WD) = weight of each dead bird after completely drained of blood and completely de-feathered.

Weight of Blood (WB) = Live Weight less Dead Weight

$$WB = LW - DW$$

Weight of Feather (WF) = Dead Weight less Weight of De-feathered

$$WF = DW - WD$$

Preparation of feather mulching film

The feather mulching film was prepared in stages as shown below in the flowchart given in Figure1.

1. Pre-treatment stage: This involved washing the feathers in mild "Omo" detergent prepared by dissolving 10 g of detergent in 1 litre of water. The detergent solution was used to remove traces of fat and dirt from the waste feathers, rinsed properly in water and air-dried the feathers. The fibers were subsequently taken to the Hammer mill at Aleshinloye market waste recycling plant for grinding.

2. Grinding the feathers: This was very difficult because of the fluffy nature of the feathers which prevented good friction with the grinding equipment. The fluffy feathers lacked enough brittleness to be properly ground. A thirty horse-power grinding machine was used to grind the feather into tiny fragments until almost powdered state was obtained. The total nitrogen, phosphorus and potassium (NPK) in the waste feathers were determined.

3. Mixing feather with glycerol: The mixing ratio for glycerol to feather-fibers was 1:3 by mass. Hence, 80 g of the feather fiber was measured and placed in a large crucible, and then 27 g of glycerol was added. The feather-glycerol mixture was properly mixed into a paste for about 15 minutes until the fibers became sticky. The glycerol was used to act as a plasticizer in the mixture.

4. Making the feather film: The sticky feather-glycerol mixture was transferred unto an aluminum foil and sandwiched between the foil, then pressed into flat film under heat of an electric iron for about 10 minutes. The film was then allowed to cool to room temperature. The prepared feather mulch is as shown in Figure. 2. The feather film is to act as a mulching film to prevent weed growth thereby reducing competition for nutrients in the soil. The film is also to release the nutrients in the feather into the soil over time after the plasticizer material diffuses out of the hydrogen bond it formed with the feather protein.

5. Application of mulching film unto the soil: After three days of planting maize, the feather mulch was applied upon the soil surface in pots of groups D, E and F. Enough quantity of feather film was sliced out and placed on the soil to cover the surface of the soil alone but avoiding the germinated plant shoot. Figure 3 shows the application of the feather mulch on the soil surface. In all the afore-mentioned analysis, data were analyzed using descriptive statistics and student t-test.

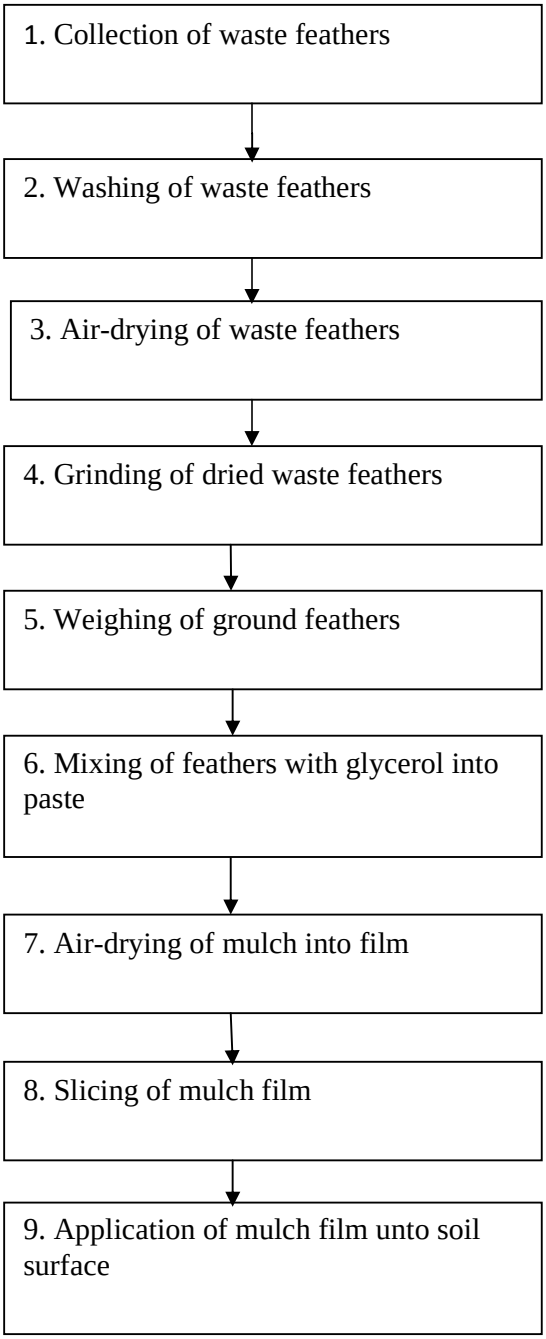

Fig. 1: Flowchart showing the stages involved in mulch preparation

Fig. 2: Sample of feather mulch before application on soil

Fig. 3: Application of feather mulch on soil surface after germination of maize seed

Results

1. Nitrogen, phosphorus and potassium (NPK) and carbon in the soil sample: The results of the analysis of N and C in the soil sample showed that the soil contained 1.8 g/kg of nitrogen and 22.4 g/kg of carbon. This amounts to C: N ratio of 12: 1. Table 1 shows the result of these nutrients contained in the soil sample.

Table 1: Characteristics of soil used in the experiment

Soil nutrient	Quantity in soil
Organic carbon	22.4 g/kg
Total Kjeldahl Nitrogen	1.8 g/kg
Phosphorus	12.6 mg/kg
Potassium	62.4 mg/kg

2. Amount of NPK available in waste feather

The percentage of total nitrogen, phosphorus and potassium (NPK) in waste feathers were obtained and the results are shown in Table 2. Waste feathers were found to contain 14.11% N, 0.18% P and 0.6% K, while the waste feathers with coloured patches contained 16.46% N, 0.13% P and 0.83% K. The higher percentage of nitrogen in the variegated (coloured) feathers (16.46% against 14.11% in white feathers (P = 0.06) was probably due to the presence of the proteinous colour pigment melanin, which contains additional nitrogen.

Table 2: Available nutrients in waste feathers

Nutrients(NPK) in feather	Amount found in white feathers	Amount found in feathers with coloured patches
Total Kjedahl Nitrogen, %	14.11	16.46
Total Phosphorus, %	0.18	0.13
Potassium, %	0.6	0.83

3. Average weight of chicken

By taking the live weights of ten samples of three species of chickens, results show the average weights to be 1.805 kg, 1.79 kg and 3.26 kg for Broilers, Layers and Breeders species respectively as represented in Table 3. These live weights show the variation in the

mass of live chickens based on their species. The average live weight of breeders was found to be the highest compared to broilers and layers.

Table 3: **Average Weight of Chicken**

Chicken Sample	Broiler (kg)	Layer (kg)	Breeder (kg)
1	2.02	1.65	3.20
2	1.69	1.85	3.64
3	1.34	1.45	2.50
4	1.37	1.55	3.52
5	2.05	1.85	4.00
6	1.85	2.10	2.51
7	1.92	1.68	3.42
8	2.10	2.05	2.40
9	1.74	2.05	4.21
10	1.97	1.65	3.30
Mean Weight	1.805	1.79	3.26
Standard Deviation	0.27	0.23	0.63

4. Percentage by mass of feathers per chicken

Table 4 shows the results of percentage by mass of feathers per chicken. Due to the light weight and fluffiness of the feathers, it was difficult to obtain and weigh all feathers from each bird. An estimation of the mass of feathers was made by comparing the live weight with dead weight (less blood) and the weight of defeathered bird (less blood and feathers). The result showed that on the average, each bird contained about 0.166 kg (8.52%) of feathers when compared with the total body mass.

Table 4: Percentage by mass of feathers per chicken (weights in kg)

Chicken Sample	Live Weight (LW)	Dead Weight (Less Blood) (DW)	Weight of Defeathered (Less Blood & Feather) (WD)	Blood (WB = LW-DW)	Weight of Feather (WF = DW-WD)	% by Mass of Feather

1	1.69	1.65	1.50	0.04	0.15	8.88
2	1.85	1.80	1.64	0.05	0.16	8.65
3	2.10	2.03	1.85	0.07	0.18	8.57
4	1.97	1.91	1.76	0.06	0.15	7.61
5	2.05	2.00	1.83	0.05	0.17	8.29
6	1.76	1.71	1.55	0.05	0.16	9.09
7	1.92	1.88	1.71	0.04	0.17	8.85
8	1.88	1.83	1.67	0.05	0.16	8.51
9	1.75	1.70	1.55	0.05	0.15	8.57
10	2.08	2.02	1.85	0.06	0.17	8.17
Mean Value	1.905	1.853	1.691	0.052	0.166	8.519
Standard Deviation	0.15	0.14	0.13	0.01	0.01	

5. Effect of mulch application on maize crop

Maize crop planted alone without mulch application in Group A was compared with Group B having Mulch application. Figure 4 shows length of leaves for Group A compared with that of Group B while Figure 5 shows length of shoots for Groups A and B. Results from this study showed that maize with mulch had longer leaves and shoots than maize without mulch.

Results show that length of leaves of maize planted alone and without mulch in Group A increased steadily up to a mean length of 35.9 ± 1.21 cm by day 28 while the length of leaves of maize in Group B planted alone and mulched also showed steady increase but much more than group A. By day 28 Group B maize showed mean length of leaves of 38.9 ± 2.1 cm. This increase in length of leaves of Group B over control Group A was significant ($P = 0.05$) by day 20. Group A mean was 25.6 ±1.6 cm and Group B mean was 27.8 ± 2.2 cm. This shows an increase of 8.59%.

Figure 5 shows that length of shoots of maize planted alone without mulch in Group A increased steadily up to a mean length of 12.7 cm ± 0.21 by day 28 while the length of shoots of maize in Group B planted alone and mulched also showed steady increase, but much more than group A. By day 28 Group B maize showed mean length of shoots of 14.4 cm ± 0.35. The increase in length of shoots of Group B over control Group A was significant from day 8 (P = 0.01) with mean shoot length of 3.1 cm ± 0.08 for Group A and 3.3 cm ± 0.08 for Group B. This is an increase of 6.45%.

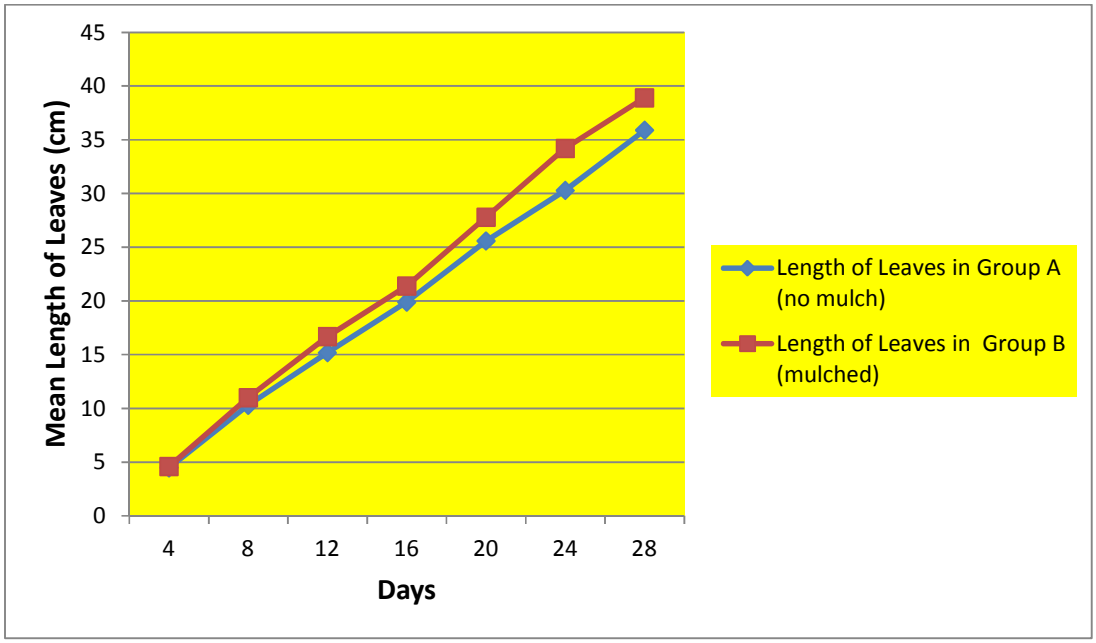

Fig.4: Mean lengths of leaves of maize in Groups A and B

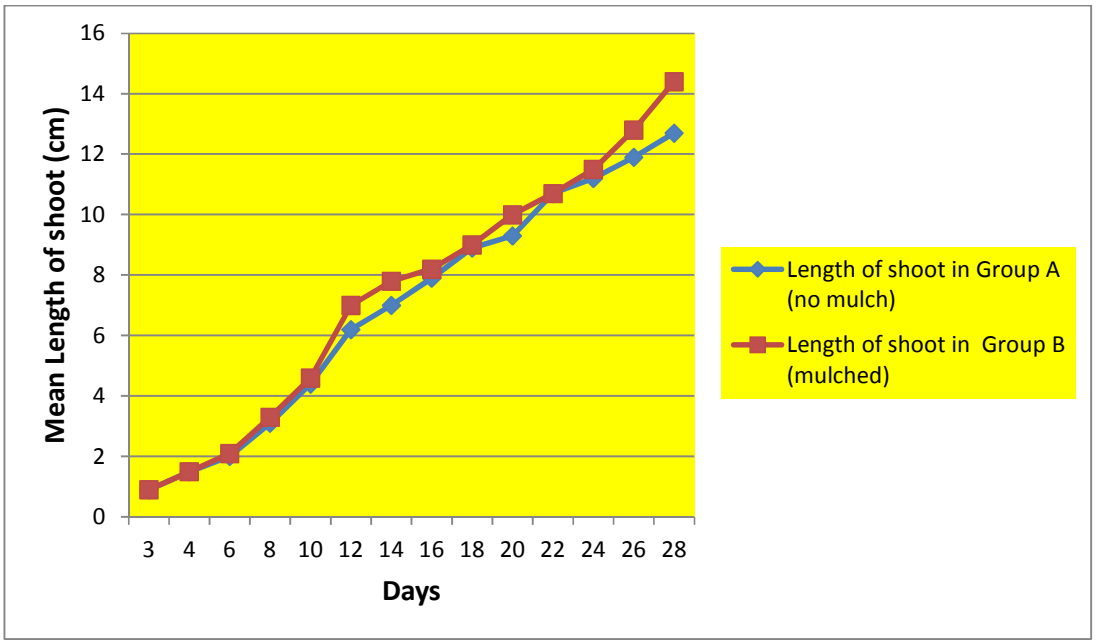

Fig.5: Mean lengths of shoots of maize in Groups A and B

Table 5: Test of significance on the effect of mulch on maize planted alone (Group A without mulch, Group D with mulch)

Test	Group	N	Day	Mean	SD	Df	t	P-value	Remark
Length of Shoots	A	8	8	3.113cm	0.083	14	-4.194	0.001	Significant at *P*=0.01
	B	8	8	3.288cm	0.083				
Length of Leaves	A	8	20	25.6cm	1.641	14	-2.256	0.041	Significant at *P*=0.05
	B	8	20	27.763cm	2.158				

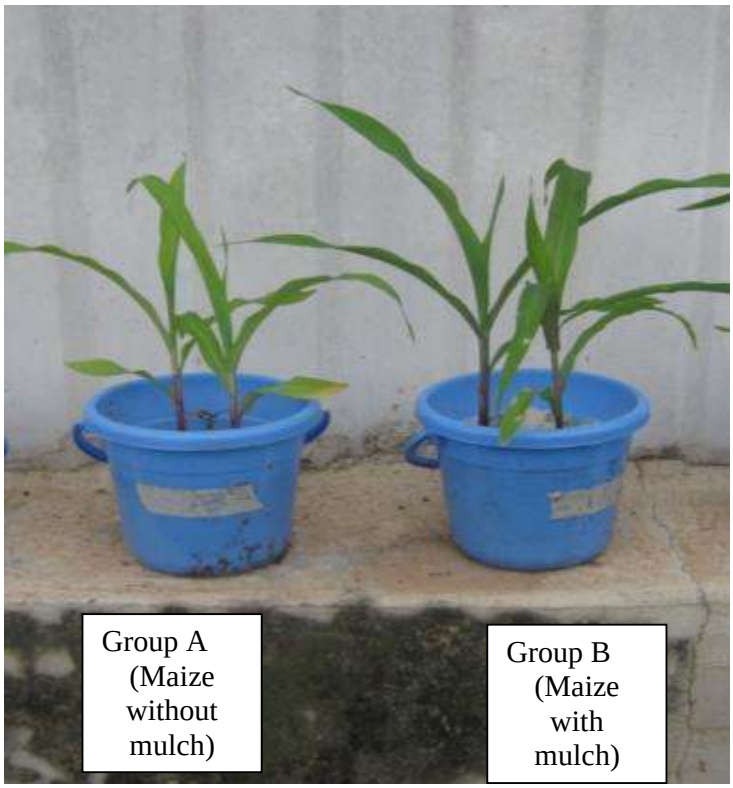

Fig. 7: Comparing maize crops in Groups A and B on day 14

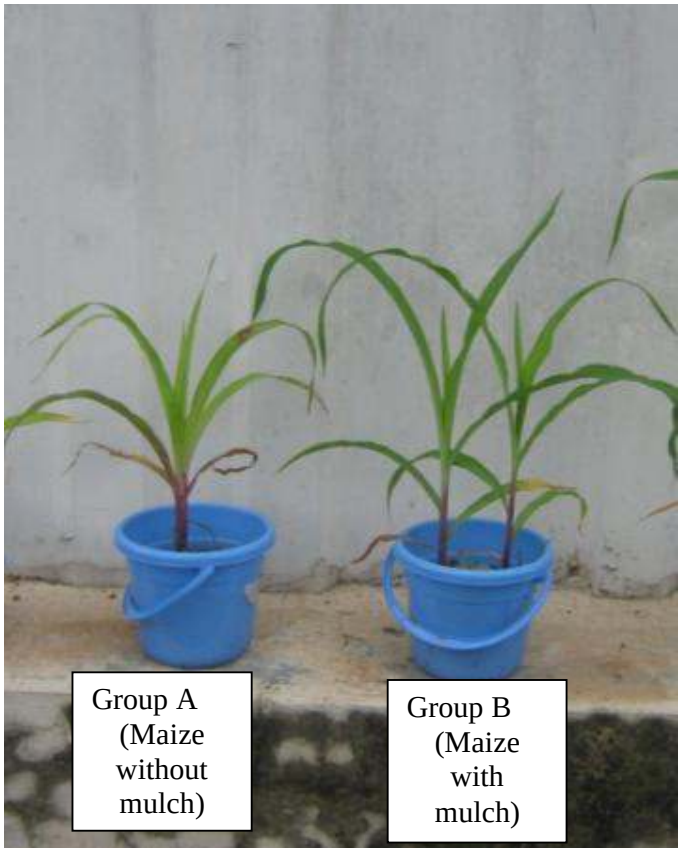

Fig. 8: Comparing maize crops in Group A and B on day 28

Discussion

5.1 Generation of waste feathers

The mean weight of a broiler chicken was more or less the same as that of the layer, while the mean weight of the breeder was relatively higher than both. This is as a result of the prolonged period of feeding of the breeder chicken and their longer life-span. Breeders are purposely kept and fed for longer periods than the other stocks. They are meant to produce quality viable eggs for production of offspring. For this reason, they are kept in good and healthy conditions. The slight differences in the mean weight of layers and that of broilers could be as a result of the table eggs the layers produce. Their protein content is usually directed to laying of eggs for consumption rather than for their own personal growth. The broilers on the other hand are kept for their meat; hence they have shorter life span, but grow faster due to the high proteinous content of their meal. In terms of quantity of feathers however, there is more concentration on the broilers due to their large quantity. For the two major poultry farms visited, a total of over 30,000 broiler birds are slaughtered daily and processed for their meat.

To obtain the percentage of the feathers from each broiler bird posed difficult due to the low density of the feather (0.89 g/cm^3). Feathers are light and fluffy and hence, require sensitive weighing scale to obtain accurate mass of the feather. In most cases, the feathers are usually plucked wet with water and this also influence the weight. An estimation of the percentage of waste feathers per bird as shown in Table 4 indicates a mean value of 8.519% as the percentage by mass of feathers per broiler bird. This is about 166 g of feathers per broiler. Most of the birds were found to be quite similar in terms of size, except some that weighed heavier than the others. As a result, lighter broilers were found to contain higher percentages of feathers than heavier broilers.

Waste feathers generated from these two farms studied amounted to about 4,980 kg per day at 0.166 kg (166 g) per bird for 30,000 birds. This quantity is large, especially as they are generated from only two poultry farms located in one Local Government Area (LGA) of Ibadan, Nigeria. In some cases, more than 20 poultry farms of similar sizes are located in one LGA in Southwest Nigeria. This implies that high quantities of waste feather, which is 20 times more than 4,980 kg, may be generated per day from the poultry farms. This

development therefore, calls for effective and sustainable method in managing the waste feathers, such as the method employed in this study.

5.2 Chemical composition of poultry feathers

The chicken feathers were found to contain enough useful nutrients for soil enrichment. The nitrogen content of 14.11% for white feathers and 16.46% for variegated feathers are high quantities that can be explored and converted for plant growth. The higher percentage of nitrogen in variegated (coloured) feathers than plain white feathers could be traced to the proteinous pigments mostly melanin, present in the colored feathers. The melanin contained additional nitrogen content within its protein structure. Based on soil nutrient rating [18], these nitrogen contents are high enough quantities which can be released for soil nutrient enrichment.

Phosphorus content of feathers was found to be 0.18% for white and 0.13% for coloured feathers. Potassium content was 0.6% for white and 0.83% for coloured feathers. After processing the waste feathers into mulching films, some of the nutrient contents, particularly the high nitrogen, phosphorus and potassium, will be much available for plant growth in the soil. The nutrients will therefore be released slowly into the soil within months as the feathers gradually degrade. The film would therefore be serving dual purposes of soil enrichment and enhancement of plant growth.

5.3 Effectiveness of feather mulching film

The effectiveness of the waste feather mulching film on growth of maize was established. Growth parameters measured were length of leaves and length of shoots. Specifically, the maize crops planted with mulch application showed a significant increase in length of leaves ($p = 0.05$) on day 20. The mean length was 27.8 cm ± 2.2, for group with mulch application against a mean of 25.6 cm ±1.6 for control group without mulch application. This was an increase of about 8.6%. The increase in length of shoots of Group B over control Group A was significant from day 8 ($P = 0.01$) with mean shoot length of 3.1cm ± 0.08 for Group A and 3.3 cm ± 0.08 for Group B. This is an increase of about 6.5%. This shows that the

mulch application provided additional nutrient for soil enrichment which helped in the growth of maize leaves and shoots.

The pots used in this project required covering with mulching film made of 14 cm diameter per pot. Twelve pots were covered with mulching film made from the waste feathers. The mulching film made for twelve pots required about 96 g of waste feather equivalent to about 58% quantity of feather from one bird. This quantity of mulching film is enough to mulch 24 seedlings of maize crop at 2 seedlings per pot (8 g of waste feather per pot). This amounts to about 4 g of waste feather required to mulch one maize seedling. This shows that producing enough film for a farmland will use a large amount of waste feather, thereby reducing the waste burden of the feathers in the farms or environment. One hectare of farmland will therefore, require about 5.195 tonnes of waste feather to mulch it. At this rate, the waste feathers generated from the two poultry farms in Oluyole Estate, Ibadan (4.95 tonnes - approximately 5 tonnes per day) can be used to produce enough mulch for one hectare of farmland. This mulch preparation will serve as a steady recipient of all waste feathers generated daily in these industries and for improved sanitary condition. In other words, the waste feather that would have constitute nuisance to the environment is converted to resource materials to produce mulch; a strategy for effective waste management in the industries.

After the planting season, there is no need to remove the mulching film from the soil because it will continue to gradually degrade in the soil releasing the nitrogen and other nutrient content of feather keratin into the soil. These nutrients will add to soil fertility for subsequent planting. This makes the mulching film useful for the purposes of soil enrichment or amendment, plant growth and waste feather management. The use of the mulching film by farmers in Nigeria will no small measure, increase crops yield and reduce over-dependent on chemical fertilizers, which has been adjudged to be inaccessible and affordable by peasant farmers. In addition, adequate and sound feather waste management can result into economic empowerment of the peasant farmers through its conversion to organic fertilizer and its use to improve crop yields [19].

Conclusion

The amount of waste feather generated showed that poultry industries generate large amount and this could be considered as resource material for mulch and organic fertilizer production.

The benefits of poultry feathers have been demonstrated in this study; therefore waste feather generation can be monitored and effectively managed. In addition, the process adopted is a sustainable method of converting the useful nutrient content of the feathers into useful products such as the mulching film. The mulching film has been shown to be efficient in enhancing maize growth and improve soil fertility.

It is becoming a common knowledge now that proper waste management can result into wealth creation from wastes, including waste feathers. The use of waste feathers to generate wealth can be achieved and sustained for the following reasons:

i. There is a large quantity of waste feathers being generated daily.
ii. Waste feather is a good source of organic nitrogen
iii. There is a sustainable means of converting the resource content of the waste feathers into mulching film.
iv. The efficiency of the film in the enhancement of crop development has been shown.
v. There is the need to increase crop production and to improve food security in the country in meeting the Millennium Development Goals (MDGs).

It is hoped that future work can further explore the use of cheaper sources of plasticiser than glycerol in order to drastically reduce cost of producing the mulching film and to make its production more profitable.

References

1. Sridhar, M.K.C. (1997). Study on living near a refuse disposal site and its impact on health and living conditions of area residents. Biocycle; 50-51.
2. Sridhar, M.K.C. (2001), UNICEF/CASSAD. Waste Management Project in Nigeria.
3. Barone, J.R. (2004). Chemical & Engineering News. Volume 82, Number 36, pp. 36-39.
4. Schmidt, W.F., Barone, J.R. (2004). New uses for chicken feather keratin fiber. Poultry Waste Management Symposium Proceedings. P 99-101.
5. Ramnani. P., Sigh, R. and Gupta, R. (2005). Keratinolytic potential of *Bacillus licheniformis* RG1: Structural and biochemical mechanism of feather degradation. Can, J. Microbiol., 51: 191-196.

6. Szabo, I., Benedek, A.,Szabo, I.M., and Barabas, G. (2000). Feather degradation with a thermotolerant *Streptomyces graminofaciens* strain. World J. Microbiol. Biotechnol., 16: 253-255.
7. Schrooyen, P.: Feather keratins: modification and film formation, 1999, Thesis, University of Twente, Enschede, The Netherlands.
8. Krimm S. (1995). National Academy of Science USA. Structure of Feather Keratin.
9. Anbu, P., Hilda, H.W., Sur, B.K. Hur and Jayanthi, S. (2008). Extracellular keratinase from *Trichophton sp*. HA-2 isolated from feather dumping soil. Int. Biodeterior. Biodegrad., 62: 287-292.
10. Eslahi, N., Hemmatinejad, N., and Dadashian, F. (2014). From Feather Waste to Valuable Nanoparticles. Int. J. Particulate Science and Technology 32(3):242-250.
11. Gaur, S., Agrahari, S., and Wadhwa, N. (2010). Purification of protease from Pseudomonas thermaerum GW1 isolated from poultry waste site. The Open Microbiol. J., Vol 3.
12. Gupta, R. and Ramnani, P. (2006). Microbial keratinases and their prospective applications. An overview. Applied microbiol. Biotechnol., 70: 21-33.
13. Mudiganti, R. K., Saranya, P. and Annadaraj, B. (2014). Isolation and Screening of New keratinolytic Bacteria from Soil at Feather Dumping Grounds. American Journal of Pharm Tech Research. 4(5): 753-770.
14. Kim, J. M., Lim, W.J. and Suh, H.J. (2001). Feather-degrading *Bacillus species* from poultry waste. Process Biochemistry. *Elsevier Science*. Vol. 37 issue 3: 287-291.
15. Kim, N. H., Dong, W. C. and Kyung, B.S. (2013). Preparation of chicken feather protein hydrolysates and isolation of iron-binding peptides. Korean Journal of Food Preservation 20(3), 435- 439.
16. Ngouajio, Mathieu, Auras, Rafael, Fernandez, R. Thomas, Rubino, Maria, Counts, James W., Jr, Kijchavengkul, Thitisilp. (2008). Field Performance of Aliphatic-aromatic Copolyester Biodegradable Mulch Films in a Fresh Market Tomato Production System. HortTechnology, 18: 605-610.
17. Association of Analytical Communities (AOAC, 2002). Methods validation and laboratory quality assurance. Gaithersburg, Maryland, USA.
18. Uponi, J.J. and Adeoye, G.O. (2000), “Soil testing, and plant analysis: an overview”. In: Akoroda, M.O. (ed.) Agronomy in Nigeria, Department of Agronomy, University of Ibadan, pp. 174-182.

19. Forgacs, G.,Alinezhad, S., Mirabdollah, A., Feuk-Lagerstedt E. and Horvath, I.S. (2011). Biological treatment of chicken feather waste