EFFECTS OF PROCESSED WASTE FEATHERS ON THE CONTROL OF WEED AND CROP ENHANCEMENT

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ABSTRACT

Management of waste feathers in Nigeria is of great concern due to large quantities generated daily. For instance, in Ibadan over 30,000 birds are slaughtered daily by two poultry industries generating large quantity of feathers. These feathers continue to end up in landfills and open dumpsites polluting the environment. Feathers contain 91% fibrous protein which is very difficult to degrade naturally due to numerous cross-linkages in the structure. Information on processing waste feathers for enhancing crop growth has not been well documented. This study was therefore aimed at assessing the effect of processed waste feathers on weed growth and crop enhancement.

The study design was experimental and laboratory based, using maize as test crop. Waste chicken feathers obtained from a poultry industry were washed, air-dried, ground into bits, then analysed for nitrogen, phosphorus and potassium contents. Eighty grams feather-bits were mixed with 27g of glycerol plasticiser at 65^0C to obtain a paste, then pressed for ten minutes into flattened organic mulch. Twenty-four 14cm diameter pots of 1.5 liters capacity were obtained and divided into six groups of four replicates each in a completely randomized design. Groups A, B, C, were controls and D, E, F, were experimental groups. One kilogramme sieved soil was placed in each pot. Maize seeds were planted in groups A and D, seeds of *Corchorus olitorius* ("Ewedu") being used as weeds, were planted in groups B and E, while Maize and "ewedu" were both planted in groups C and F. Surfaces of the soil in the experimental groups were covered with feather mulch while control groups were not mulched. All pots were sprinkled with water daily. Growth of weed and crop were measured for 28 days using flexible measuring tape. Data were analysed using descriptive statistics and student t-test.

About 4980Kg of feathers are generated daily from two industries (0.166Kg or 8.52% by mass per chicken). Feathers contained 14.1% nitrogen, 0.2% phosphorus and 0.6% potassium. Mean length of maize shoots in group D (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 leaves showed significant increase ($p< 0.05$) on day 20 at 27.8 ±2.2cm over control at 25.6 ±1.6cm. Mean length of maize shoots planted with weed in group F showed significant increase ($p< 0.01$) on day 4 at 1.6 ±0.1cm over control group C at 1.5

±0.1cm, and significant increase (p< 0.01) in mean length of leaves on day 6 at 8.1 ±0.5cm against 6.1 ±0.4cm for control. There was zero weed growth by day 28 in groups E and F with mulch against control groups B and C showing 6.78 ±0.1cm and 5.8 ±0.1cm respectively as mean length of shoots of weeds. The mulch totally controlled weed growth by 100% and increased growth of maize shoot and leaves by 71.1% and 61.9% respectively.

Organic mulch made from processed waste feathers was effective in weed control and crop enhancement. Therefore, it can be a useful strategy for waste management.

KEY WORDS: Organic Mulch, Feathers, Weed control, Waste management.

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DEDICATION

I dedicate this dissertation to the ALMIGHTY GOD, the greatest Environmentalist, whose original concept of the earth as typified by the Garden of Eden, is a healthy and beautiful habitation for biodiversity. May He help us re-establish Eden again.

CERTIFICATION

We certify that this work was carried out by Mr Ayorinde Olubunmi Awe at the Environmental Health Sciences Department, Faculty of Public Health, College of Medicine, University of Ibadan, Nigeria.

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ABBREVIATIONS

AOAC	-	Association of Official Analytical Chemists
APHA	-	American Public Health Association
cm	-	Centimeter
cm/day	-	Centimeter per day
$FeSO_4$	-	Iro (ii) tetraoxosulphate (vi)
FOS	-	Federal Office of Statistics
g	-	Gramme
H_2O	-	Chemical formula for water
HCl	-	Hydrochloric Acid
$HClO_4$	-	Tetra oxo chlorate (vii) Acid
HF	-	Hydrogen Fluoride
H_2SO_4	-	Tetra oxosulphate (vi) Acid
HNO_3	-	Tri oxonitrate (v) Acid
IAR&T	-	Institute of Agriculture, Research & Training
$K_2Cr_2O_7$	-	Di potassium heptaoxochromate (vi)
KH_2PO_4	-	Potassium hydrogen tetraoxophosphate(v)
$KMnO_4$	-	potassium tetraoxomanganate (vii)
Kg	-	Kilogramme
M	-	Molar solution or mole per litre
ml	-	Milli litre
mm/Kg	-	Mill mole per kilogramme
NaOH	-	Sodium H Hydroxide
^0C	-	Degree Celsius
P_2O_5	-	Phosphorus pentaoxide
ppm	-	Parts per million
pH	-	Measure of acidity, alkalinity or neutrality of an aqueous solution
SD	-	Standard Deviation
UNICEF	-	United Nations International Children's Education Fund
USEPA	-	United States Environmental Protection Agency
WHO	-	World Health Organisation

CHAPTER ONE

INTRODUCTION

1.1 Background of Study

A "waste" is any material resulting from domestic activities or industrial operations for which there is no economic demand and so must be disposed of (Sridhar, 2000). All over the world millions of tons of solid waste are generated from human activities in both urban and rural settlements. The burden of solid waste management is of particular concern in many cities of the world due to rural-urban migration and globalization. For instance, in the United States alone, more than 229 million tones of solid wastes were generated in 2001. This approximates 4.5kg of waste per person per day (USEPA, 2001). Brazil generates about 90 tones of solid waste daily (Wells, 1994). In Nigeria, solid waste generation has been on the increase. By the turn of this century, it is estimated that Nigerian cities will produce between 8,518 tones of municipal wastes in New Bussa and 98,081 tones in Lagos per year at the rate of 0.43kg per capita per day (Sridhar, 1997). In Dugbe, one of the markets in Ibadan, it was estimated that the total wastes generated per year was over 827 tones (Oluwande, 1983). The negative impact of solid wastes on the environment is on the increase despite measures put in place by stakeholders in waste management. Major cities around the country are characterized by open dumps in strategic locations even to the disappointing visitors. Apart from the unattractive sight caused by solid wastes, the increase in the incidence of vector-borne diseases as a result of poor solid waste management is a source of concern.

The contribution of waste feathers to the quantity of solid wastes generated world-wide has been on the increase since 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 (Barone, 2004). Rough estimates put the amount of feather waste generated by the poultry industry in the USA between 2 and 3 billion lb (0.9 to 1.4 billion Kg) per year. Getting rid of these feathers is very difficult. They are either burned, buried, or ground up into feather meal and fed to livestock. These methods of waste feather management are costly and controversial.

1.2 Statement of Problem

In Nigeria, poultry chickens form major sources of cheap animal protein for the population. Several festive seasons celebrated almost every month of the year also make demand for poultry products very high. In Ibadan, two poultry industries in Oluyole estate slaughter over 30,000 chickens per day and therefore generate large amount of poultry feather wastes of up to 4980kg (about 5 tons). In the United States, the poultry industry discards 2 million tones of chicken feathers as wastes annually (Schmidt and Barone, 2004). In addition, several thousands of tones of poultry feathers are generated annually after slaughtering the chickens. Chicken feather wastes contain fat, water, blood and soluble proteins. These poultry feathers are usually disposed of in landfills where they constitute environmental problems because they are not easily biodegradable in the soil. Although some of the waste feathers can be autoclaved and turned into low-value animal feed, the rest must be disposed of and thus still create a large waste problem for the poultry industry. The practice of converting waste feathers into animal feed is still not well practiced in Nigeria and where it is practiced, it has not been economically viable. Furthermore, the use of waste feathers for making organic mulch has not yet been well documented in Nigeria. Hence this study intends to identify a more economically sustainable method of handling waste feathers.

1.3 OBJECTIVE

1.3.1 Broad Objective

The broad objective of this study is to process waste feathers into useful mulch for the dual purpose of controlling weed growth and enhancing crop growth.

1.3.2 Specific Objectives

The specific objectives are:

1. To assess the quantity of poultry waste feathers generated in selected poultry industry in Oluyole Estate area of Ibadan
2. To determine some physico-chemical composition of the waste feathers
3. To establish suitable and sustainable method of converting the waste feathers into mulching film.

4. To measure the efficiency of the mulching film on weed control and plant development in a greenhouse experiment using a selected crop.

1.4 Significance of the Study

The magnitude of solid waste generation in major cities in Nigeria has reached an alarming rate that calls for concern. Cities like Lagos and Ibadan generate almost 0.5Kg waste/capita/day while the national average was 0.45Kg waste/capita/day (Sridhar, 2001). 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. Hence, poultry feathers have been put to various uses in the past. Products like handbags, wreaths, shawls, decorations, hand fans and so on have been made from poultry feathers. The demand for these products however, has not made the use of the feathers in these directions very viable. There is need to carry out further work to achieve a more demanding product from the feather wastes. This project intends to convert the resource in poultry feathers into a product which will significantly reduce the burden of agricultural weeds and ultimately reduce the cost of food production, in addition to increasing crop yield, thereby promoting food security.

1.5 Justification of the Study

Feather wastes can be transformed into useful materials such as protein-based mulching films are not yet in use in Nigeria. Other available mulching methods include polyethylene mulching films. 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 described herein will slowly degrade into the soil within six months to one year before the next planting season. 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. As soon as water exchanges with the plasticizer in the protein structure, the films will be embrittled and will begin to crack under environmental stress such as wind, rain, and microbial activities. When the field is turned over for the next planting season, the films will be easily broken up and incorporated into the soil. Proteins degrade when enzymes attack them and the enzymes that degrade keratin naturally occur in the soil microorganisms. Proteins contain large amount of nitrogen and therefore have the added benefit as serving as additional nitrogen sources, or fertilizer, for the soil as they are enzymatically degraded. It is therefore beneficial to investigate the conversion of feather keratin into the mulching films as means of managing the feather waste.

CHAPTER TWO

LITERATURE REVIEW

2.1 Solid Waste in the Environment

The environment refers to all external factors which are living and non-living materials that surround man. These include the social and economic conditions in which man lives (Park, 1997). The World Health Organisation (WHO) defined Health as a state of complete physical, mental and social well-being and not just the absence of diseases or infirmity. Hence, Environmental Health could be defined as 'all the external factors that surrounds man which can maintain his complete physical, mental and social well-being and not just prevent disease or infirmity'. This makes the term 'Environmental Health' a better replacement for the term 'Environmental Sanitation' which mainly focuses on absence of germs.

To ensure complete health of the environment, WHO has identified the following as the major components of environmental health:

1. Water Sources and Quality
2. Solid Waste Management
3. Housing Quality and Health
4. Food Safety and Hygiene
5. Sewage Management
6. Vector Control
7. Air Pollution and Control
8. Hazard Management.

The management of waste poultry feathers comes under the component of solid waste management.

Waste can simply imply anything 'useless or valueless' or any substance which is broken, worn-out, contaminated or spoilt and is required to be disposed of. Sridhar (2000) on the other hand defined waste as 'any unwanted material generated from domestic activity or industrial operations for which there is no economic demand and which must be disposed'.

Wastes can be classified as gaseous, liquid or solid waste depending on their physical state (Peavey *et al.*, 1985; Sharma and Kaur, 1994). Solid wastes are wastes resulting from domestic, industrial and agricultural activities which encompass wastes from municipal and commercial activities as well as homogenous wastes from similar industries and institutions (Sridhar and Taiwo, 2000). Solid wastes include waste poultry feathers under study in this project.

Solid waste management includes all the processes and stages involved in the handling of solid wastes that lead to its control. So far several measures are currently employed in solid waste management.

Waste Generation encompasses activities in which materials are identified as no longer being of value and are either thrown away or gathered together for disposal. In Nigeria, municipal solid waste is produced at 0.43kg per head per day and 60-80% of it is organic in nature (Sridhar, 1999). Waste handling and separation involves the activities associated with management of waste until they are placed in storage containers for collection. Handling also encompasses the movement of loaded containers to the point of collection. Separation of waste components is an important step in the handling and storage of solid waste at the source. This stage requires a lot of understanding and cooperation by those that generate the solid waste. This stage helps to separate the wastes into various categories such as recyclables and non-recyclables, to ease subsequent stages of management.

Waste Collection is the most difficult and most expensive aspect of refuse disposal practice. It can cost up to 80% of the total cost of refuse disposal (Oluwande, 1983). The process involves storage in production premises, collection at intervals and transport to disposal site. These three steps require proper resource planning, employment of appropriate technology and community mobilization for sustainability. Occasionally, some facilities are used for the recovery of waste materials that have been separated at the source. These include curbside collection, drop off and buy-back centers. The transfer of wastes may be from the smaller collection vehicle to the larger transport equipment or the subsequent transport of the wastes usually over long distances, to a processing or disposal site. Waste Disposal refers to the processes adopted to ensure that the solid waste does not cause nuisance any longer in human environment. Various options are available for use depending on government policy and type of waste generated. Generally, common methods employed include Sanitary landfill in approved dump sites, Composting, Incineration (controlled or open-air), Disposal in the sea, Bailing and Compression, Pyrolysis and Pulverization

Today the disposal of wastes by land filling or land spreading is the ultimate fate of all solid wastes, whether they are residential wastes collected and transported directly to a landfill site, residual materials from materials recovery facilities (MRFs), residue from combustion of solid wastes, compost or other substances from various solid waste processing facilities. The proportion of Nigerian households who dispose refuse through personal and government bins is 13%. The others (80%) dispose around the homes and in places where it constitutes health hazards (F.O.S., 1996). A modern sanitary land is not a dumpsite but an engineered facility used for disposing of solid wastes on land without creating nuisance or hazards to public health safety, such as the breeding of rats and insects and the contamination of ground water. Some of these other methods are hygienic and environmentally friendly while others are not. The best option however depends on the type of waste to be handled. There is therefore the need to first determine the composition of the waste before ascertaining the best disposal method to manage such waste.

Waste Characterization involves the determination of the physical and chemical composition of the waste with the aim of separating them according to similarity in composition (Stidlar, 1999).

Physical Composition of wastes varies according to standard of living, customs, the food habits, climatic conditions and other factors. Variations also occur in waste quantity and quality with days of the week, with weeks of the month, and even months of the seasons. Quantity of solid waste produced at weekends is often more than that of other days of the week due to weekend shopping. Quantity and quality of solid waste also vary with the people in different parts of town. Solid waste from the government reserved area (GRA) of Ibadan comprise of about 65% garbage, while the old town areas have their solid waste made up of over 81% leaves (Oluwande, 1974).

Chemical Composition of waste is also important because it shows the chemical make-up of the waste and helps in the selection of the appropriate disposal method. Wastes that are suitable for composting are determined by their chemical composition. Wastes with necessary carbon-nitrogen ratio will make excellent material for composting (Oluwande, 1974).

2.2 Solid Waste Management

For proper and efficient waste management, there is need to adopt sanitary and friendly practices which enable efficient management of our solid wastes. Various refuse management methods can be grouped under various categories based on the objective of the method.

Waste Transfer Methods involve removal of wastes from human environment to other environment such as dumping in the sea or other sites. It will be noted that this method tends to further pollute the new receiving environment and may adversely affect biodiversity. Waste Burying Methods involve hiding the waste from human environment such as landfills and controlled tipping. These methods may be inappropriate if the wastes are non-biodegradable or not easily biodegradable and will remain undegraded in the earth for a long time. There is also the problem of leachate from buried wastes which may eventually pollute nearby underground water.

Waste Conversion Methods are those involving conversion of wastes into other useful forms such as recycling. This is the best method employed for non-biodegradable wastes. Of all these waste management categories, the waste conversion methods that involve waste stabilization and conversion are the best environmentally-friendly options.

Waste Classification: Wastes can be classified based on different criteria. When considering the possibility of being decomposed in the soil, we can have biodegradable, semi-biodegradable and non-biodegradable wastes.

Biodegradable Wastes are wastes which can easily be degraded by microorganisms after disposal. They are easily acted upon by these microbe agents until the wastes become stabilized in the disposal site. Such wastes are usually organic in nature. The period of degrading depends upon the chemical composition of the wastes and the prevailing physical conditions in the disposal site. Examples of biodegradable wastes and the period of their degradability are banana peel (2 months), notebook paper (3 months), comic book (6 months) and wool mitten (1 year) (Cornell Univ. Cooperative Extension, USA).

Semi-Biodegradable Wastes are wastes that can also be degraded by microorganisms but will require longer period of degrading into stable composition. The wastes usually may persist for years before being degraded. Such wastes usually consist of high molecular mass chemicals, natural polymers and complex compounds that require certain enzymes for degrading. Examples include poultry feathers, crab shells, groundnut husks, melon husks, leather, corn cobs, coconut shell, hair, hooves and nails.

Non-Biodegradable Wastes are wastes that cannot be degraded naturally by microorganisms and thus will remain in the disposal site. Such wastes are usually synthetic polymers, plastics, metals glass, nylon, rubber and bones.

Recyclable Wastes are wastes that can be processed and converted back to the material anew or to another material close to the original one in composition. Most non-biodegradable waste materials are best handled by being recycled back into useful products. Examples of recyclable wastes and their products include paper wastes convertible to newsprint and tissue paper, cans convertible to new cans and extracted aluminium, metal wastes convertible to iron billets, plastic wastes converted to plastic pellets, wood converted to particle boards and glass converted to new bottles.

The focus of this project is on poultry feathers which are classified as semi-biodegradable wastes. Despite the animal origin, feathers contain high molecular mass chemicals which are tightly inter-woven in their structure. Their complex structure makes it difficult for microorganisms to easily degrade the feathers hence their classification as semi-biodegradable.

2.3 Structure of a Feather

Feathers are the covering of poultry and birds. Poultry feathers form between 6-9% of the total weight of a chicken. Feathers are composed of about 91% protein, 8% water and 1% lipids. The type of protein in feathers is called Keratin, sulfur containing fibrous protein. The structure of the keratin gives the feather its strength and suppleness. The two types of feathers most commonly used are the contour and down feathers. Contour feathers are those found on the backs and wings.

Plate 1 shows the structure of a feather with the main parts while plates 2 and 3 show the contour and down feathers. The central stem, or rachis, of the feather is constructed of a thin, solid outer layer. The interior is thick and spongier, stiffened by internal ridges. The rachis is more commonly referred to as the quill. Barbs project from either side of the rachis to make up the body of the father, or vane. Each barb has a fine network of barbules. Interlocking hooklets on the barbules give feathers their stiffness and flexibility. It is the undamaged hooklets which allow you to run your fingers up a split vane and make it whole again.

The down feathers are usually found under the contour feathers where they provide warmth for the bird. These feathers have shorter quills and barbules without hooklets. This gives the down feathers a softer, fluffier appearance.

Plate 1 shows the typical structure of a feather.

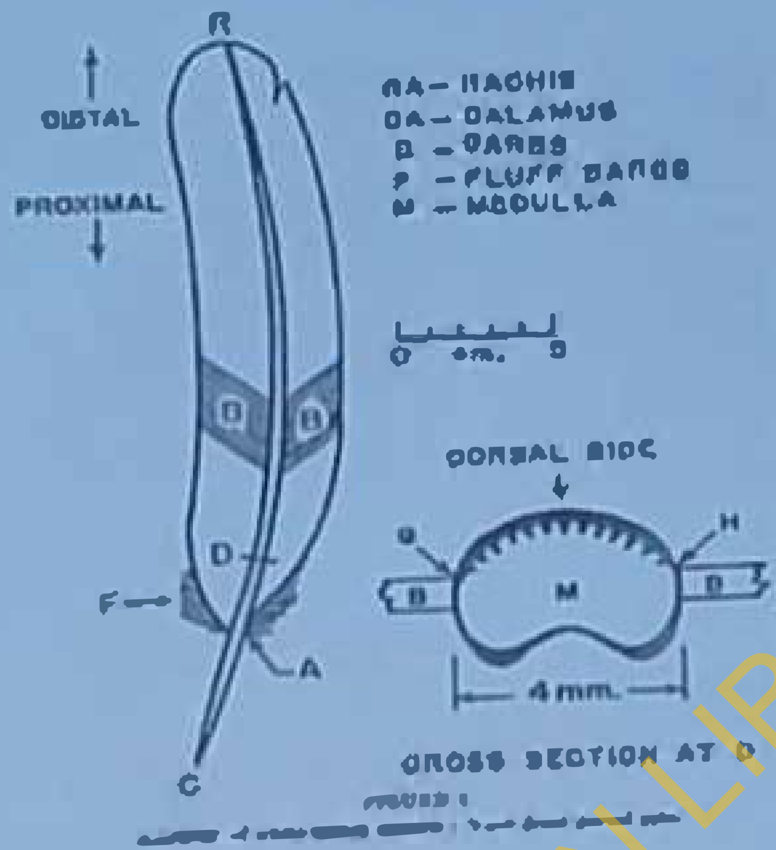

Plate 1: Structure of a Feather

Source: National Academy of Science- National Research Council, USA. 1995.

Plate 2: Chicken Feather

Source: National Academy of Science- National Research Council, USA, 1995.

Plate 3: Contour and Down Feathers

Source: National Academy of Science- National Research Council, USA 1995.

2.4 Chemical Composition of Feathers:

Feathers have been found to contain the protein keratin as the major nitrogen-containing substance. Keratin is a fibrous structural protein normally found in hair, nails, hooves, wool, feathers and skin. A quarter of amino acids in keratin are cysteine, whose ability to form strong bridging (disulphide) bonds with other cysteine units accounts for keratin's great stability. Keratin does not dissolve in cold or hot water and does not easily undergo proteolysis (Schrooyen, 1999). Its fibers are 10-12% longer at maximum water content (about 16% than when dry). The sulphurous smell of burning keratin is distinctive.

Keratin may be divided into two major classes, the soft keratins (occurring in skin and a few other tissues) and hard keratins, forming the material of nails, claws hair, horn and also in feathers and scales. The hard keratins may in turn be further subdivided into structural types described as α-keratin, β-keratin, or feather keratin. Keratins of the α and β types have different predominant structural motifs in their proteins. In the former case, supramolecular structures based on the α-helix secondary structure of protein chains, and in the latter case on the β-pleated sheet motif.

All keratins are characterized by a high level of the sulphur-containing diamino-acid cystine, which acts as a cross-linking point between protein chains (Krimm, 1995). 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. Cystine contents vary widely in the keratins, which are reflected in their variations in mechanical properties (Krimm, 1995).

Keratins are major structural proteins of all epithelial cell types and appear to play a major role in wound healing. The characteristics of toughness and insolubility typical of hard keratins are desirable properties in many industrial materials. In addition, keratin materials are biodegradable and produced from a sustainable resource and as such they have significant potential for use as a substitute for oil-based polymers in many applications such as films, fibers and adhesives (Schrooyen, *et al.*, 2000). Their use in cosmetics and personal care applications is already well established and an extension to medicals has been proposed

The amino acid sequence of a single polypeptide chain, B-4, from fowl feather barbs has been determined (Schrooyen *et al.*, 2000). The B-4 chain was found to consist of 96 amino acid residues and to have a molecular weight of 10206 in the S-carboxymethylated form. The N-terminus of this protein was an N-acetylserine residue. The B-4 protein contained seven S-carboxymethylcystine residues, six of which are located in the N-terminal region (residues 1-26), and other one in C terminus. The central region of the peptide chain was rich in hydrophobic residues. There were homologous amino acids at 66 positions in the sequences of the feather keratins of fowl, emu and silver gull. The variation (substitution, deletion and insertion) in sequence was found to be localized in both terminal sections of the polypeptide chain.

The B-4 protein structure was predicted to contain β-sheet structure is mostly located in the central region (residues 22-70). On the other hand, both terminal regions are almost devoid of secondary structure.

Table 1: Amino Acid Components of Feather, Hair & Wool

General Analysis	Specific Analysis	Chicken Feather	Hair	Sheep Wool
Component	Total Nitrogen	15.0-16.2%	15.5-16.6%	16.2-16.9%
	Amide Nitrogen	1.09	1.17	1.1-1.37
	Suphur	2.3-2.9%	5.0-5.24%	3.0-4.0%
Non-polar Hydrocarbon residue	Glycine	7.2-9.5	4.1	5.2-6.5
	Alanine	2.0-5.4	2.8	3.4-4.4
	Valine	8.3-8.8	5.5-5.9	5.0-5.9
	Leucine	7.4-8.0	6.4-8.3	7.6-8.1
	Isoleucine	5.3-6.0	4.7-4.8	3.1-4.5
	Proline	8.8-10	4.3-9.6	5.3-8.1
Acidic residues	Aspartic	5.8-7.5	3.0-8.0	6.4-7.8
	Glutamic	9.0-9.7	13.6-17.9	13.1-16.0
Aromatic residue	Phenylalanine	4.7-5.3	2.7-3.6	3.4-4.0
	Tyrosine	2.0-2.2	2.2-3.5	4.0-6.4
	Tryptophane	0.7-0.9	0.4-1.3	1.8-2.1
Basic residue	Histidine	0.3-0.7	0.6-1.1	0.7-1.1
	Lysine	1.0-1.7	1.9-3.8	2.8-3.3
	Arginine	6.5-7.5	8.9-10.8	9.2-10.6
	Hydroxyl-lysine	-	0	0.2
Hydroxy-containing	Serine	10.2-14	7.5-10.6	7.2-9.5
	Threonine	4.4-4.8	6.3-8.5	6.6-6.7
Sulphur-containing	Cystine	6.8-8.2	14.4-18.0	11.0-13.7
	Methionine	0.4-0.5	0.5-1.0	0.5-0.7

Source: Schrooyen *et al.* (2000)

2.5 Agents of Physical Disruption of Feathers

More recently, researchers have explored the failure properties of keratins and the modulating influence of the environment on its properties. As feathers are replaced on the birds only infrequently at moult, they should be robust enough to withstand the rigours of their environment. It has long been known that feathers containing the pigment melanin, which gives rise to black and dark brown colouration, suffer less wear than adjacent, paler areas of feathers. Microhardness tests confirmed that this observation had a basis in differences in microhardness as melanic keratin is significantly harder than non-melanic keratin. Various agents that can lead to the disruption of the feather structure integrity.

Infestation of feathers by insects is quite common. Because keratin contains sulphur, it is an attractive food item to some types of insects. Clothing moths and dermestid beetles are especially fond of keratin-containing materials. In Hawaii, the most common type of clothing moth is the case making clothes moth *Tinea pellionella (L)*. It is approximately ¼ inch long, with a slender, dusty-brownish body. On close inspection, the moths have a characteristic pattern of three indistinct dots on the lower portion of each wing. Adults have no mouth parts and cannot eat feathers. It is the larvae, identifiable by the tubular shaped cases that it spins, which causes damage. Often pieces of the feather that the larva is feeding on are inclined in the case so that cases are similar in colour and texture to the feathers. Larvae cannot live outside of their cases. Dermestid beetles also feed on keratin containing materials. Two of the many beetles found in Hawaii are the common carpet beetle *Anthrenus scrophulariae (L)* and the varied carpet beetle *Anthrenus verbasci (L)*. Again, it is the larvae which feed on and damage feathers. The larvae appear fuzzy because of the numerous hairs which extend from their bodies. A tell-tale feature of the dermestid beetle is that the tail hairs are longer than the dorsal, or side hairs. Larvae often appear larger than the mature adult beetle.

Dust is another agent that can disrupt the feather structure. Dust is readily caught and embedded in the feather structure. Oils on the surface of the feather can also trap and hold dust. Dust in some industrial areas commonly contains mineral particles and cellulose fibres. The abrasive quality of the mineral component can tear or damage hooklets and barbules if dust is not removed carefully. The salt and fibrous components tend to attract and hold moisture. Deterioration is accelerated, especially in very acidic or alkaline environments. Surface deterioration will result in loss of the sheen and smooth nature of feathers.

Another obvious cause of damage to feather structure and fading of feather colour is exposure to light. Although less obvious, light may also cause other types of damage. As the energy contained in light strikes the feathers, it will begin to break molecular bonds. The breaking of these bonds results in colour fading or change, yellowing and embrittlement of the feathers. If the feather is exposed to direct and intense light, damage occurs very quickly and is immediately obvious. Just as dangerous is the exposure to moderate light levels over extended periods of time. Light damage is however cumulative and will slowly build up over the years. Although decorations made with feather may have been hanging in a dim corner of the living room, over the years the daily exposure to low light levels will add to gradual deterioration. Usually the first indication of damage is a littering of small pieces of broken feather barbs on the floor.

Extreme pH values can also damage the integrity of feathers. pH is the arbitrary measurement of acidity and alkalinity. Acidic environment (pH 6 or lower) will cause the gradual chemical breakdown of the keratin leading to weakening of the feather. The rate of damage will increase as temperature and relative humidity increase. Alkali (pH 8 or higher) can also cause feather to degrade. Alkali will affect much more of the keratin structure than acids, which are fairly specific in breaking down only the amino acid tryptophan.

Temperature and Humidity will also greatly affect feathers. Below 35% relative humidity, feathers rapidly desiccate. They become quite dry and brittle, and barbs will break off at the slightest pressure. In conditions of prolonged high humidity, acid hydrolysis is accelerated and even low quantities of acid in the feather or surrounding environment will cause feather breakdown.

Heat acts as a catalyst in many chemical reactions. High temperatures will speed the breakdown of feathers. In general, ambient temperature and daily fluctuations have fewer negative effects on feathers than seasonal changes in humidity.

Mechanical Abrasion is one of the easiest ways to damage feathers. Handling or use of feathers will break the delicate hooklets and barbules to contour feathers. It is extremely easy to bend or break the quills, and to abrade the surface of the feathers destroying surface pigmentation and iridescence. The more handling the feather receives, the likelier chances are that irreversible damage will occur.

2.6 Treatments of Keratin

All feathers are composed of the natural biopolymer fiber keratin. Harvesting this fiber in a viable commercially useful form to make value-added products has proven successful at the pilot scale level. Prototype products formulations include: high flow, high surface air filters, light weight insulation mats, composites with natural and synthetic polymers, strong lightweight protein based construction materials, and biodegradable agricultural weed control films (Schmidt and Barone, 2004).

The feather protein, Keratin has been subjected to various methods of processing using different techniques. The particular method and technique employed depends on the desired end-result and the ultimate product expected from keratin.

One process for the solubilization of keratins is using sodium sulphide whereby the cystine/cysteine groups remain essentially unmodified. The keratins are again extracted using a metal sulphide solution, treated with an alkali metal sulphite solution, and then acid-precipitated. The resulting protein product is described as being dispersible in water-alcohol mixtures, and can be used for preparing films and coatings. The process also describes alternative processes for extracting and solubilizing feather keratins, including treatment with mercaptoethanol-alcohol-water mixtures; or treatment with alkaline mercaptoethanol-alcohol-water mixtures containing alkali metal hydroxides. However, according to Schrooyen (1999) the cystine/cysteine groups remain essentially unmodified. A major disadvantage of solubilised keratins with essentially unmodified cystine/cysteine is that they do not allow researchers to produce keratin-based products, in particular films and coatings, with the desired mechanical properties. In particular, such films suffer from brittleness.

The pH at which the keratins are solubilized is alkaline, i.e. higher than pH 7.0. Preferably however, solubilization is performed at an alkaline pH that is at least pH 8.0, 8.5, 9.0, 9.5, however, more preferably the pH is at least or higher than pH 10.0, 10.5, 11.0, 11.5, 12.0, or 12.5 because at a pH at higher than pH 10.0 the dissociation equilibrium of sulphide shifts towards S^{2-}, which is a stronger reducing agent than is HS^-. However, the pH should not be higher than pH 13.5.

The least temperature at which the keratins are solubilized is at 20°C. However, preferably higher temperatures are used for solubilization, such as a temperature of 30, 40, 50, 60, 70 or 80°C but preferably not higher than 100° C.

The duration of the keratin solubilization step is primarily chosen such that the desired degree of hydrolysation of the solubilized keratin is obtained under the given solubilisation conditions. Typically the solubilisation will take between 10minutes and 24 hours. The duration of the keratin solubilisation may be further optimised for the yield of solubilisation. Thus the skilled person will empirically optimise the set of conditions for keratin solubilisation in order to obtain at least the desired degree of keratin hydrolysis and preferably the highest yield of solubilised keratin.

Most of the methods mentioned thus far dates back to the late 1960's and early 1970's Nevertheless, in the 30 years following, these methods have not led to any widespread use of the keratin-derived products disclosed therein. This is probably because the products and processes described are not economically viable--despite the fact that they employ waste feathers as a starting material--and/or because the keratin products obtained do not show the properties required for practical (e.g. commercial) use.

Some of these problems are addressed in the thesis of one of the inventors that describes keratin-derived products obtained by partial modification (i.e., alkylation) of intact feather keratins using monoiodoacetamide, monoiodoacetic acid or monobromosuccinic acid in concentrated aqueous urea solution and in the presence of 2-mercaptoethanol. The keratins were modified to degrees of modification varying between 25 and 87%, calculated on the basis of the amount of remaining free –SH groups. This partial modification provided stable dispersions of essentially intact (i.e. non-hydrolysed), partially modified keratins, which could be used to cast strong films with desired thermal and mechanical properties. However, extraction and solubilisation of essentially intact keratins for partial modification requires the use of high concentrations of chemicals such as urea and 2-mercaptoethanol. The use of these chemicals at experimental scale is acceptable. However, their use at large scale is not economically feasible because the use of these chemicals is expensive, also in view of the environmental and occupational hazards associated with the use of these chemicals, requiring expensive precautionary measures.

Thus, there is still a need for an economically viable method for the processing of keratin-containing (waste) materials such as feathers, which can be used to provide a range of keratin-based products, in particular films and coatings, with properties acceptable for practical/commercial applications.

It has now been found that improved keratin-based products can be obtained by a process which involves a combination of partial degradation, usually by means of hydrolysis, of the keratin molecules and partial modification of the free –SH groups, i.e. the free –SH groups resulting from cleavage of the disulphide bonds . In particular, the method provides such a partially degraded and partially modified product that is dispersible in water and that can be used in a range of applications, including but not limited to those discussed herein below.

Thermally processing natural keratin is difficult because of the permanent cross-links. The keratin must first be reduced (i.e., covalent sulfur-sulfur bonds must be broken) to get a soluble fraction for further processing (Bonser *et al.*, 2004). There are many techniques to reduce keratin such as acid and alkaline hydrolysis, alkaline sodium sulphide treatment, enzymatic treatment and ammonium copper hydroxide treatment. These result in S-S reduction and peptide bond breakage. The sulfur-sulfur reduction is an advantage but peptide bond break is a disadvantage. Sulfitolysis with performic acid and use of thiols in concentrated urea solutions at alkaline pH will selectively reduce S-S bonds without peptide bond breakage. The thiol technique appears to be the currently preferred method because the S-S bonds can re-form easily after processing. However, reduction requires multiple chemical treatment steps, sufficient time for reaction and subsequent processing to eliminate the chemicals used for treatment. Therefore, reduction of even small amounts of keratin requires hours to days.

The reducing agent for solubilisation at alkaline pH may be chosen from sulphides, thiols, boric hydride and phosphines, or combinations thereof. Preferred sulphides are alkali metal sulphides, such as sodium sulphide. At lower alkaline pH, e.g. at a pH lower than 10, 9.5 or 9.0, ammonium sulphide may also be used as reducing agent for solubilisation.

the use of which allows to avoid a salt residue in the final product. Preferred thiols are dithiothreitol, 2-mercaptoethanol and thioglycolate and a preferred phosphine is tri-n-butylphosphine.

The conditions of solubilisation, (i.e. the concentrations of the keratin-fibre containing starting material, the reducing agent(s), and buffer, and the pH, temperature and duration of solubilisation) are preferably chosen such that a satisfactory yield of solubilised keratins is obtained, preferably at least 10, 20, 30, 40, 50 or 60% of the keratin in the keratin-fibre containing starting material are solubilised. The conditions of solubilisation are further preferably chosen such that the solubilised keratin is partially hydrolysed.

Keratinase isolated from *Bacillus licheniformis* PWD-1 was immobilized on controlled-pore glass beads. The immobilized keratinase demonstrated proteolytic activities against both insoluble feather keratin and soluble casein. It also displayed a higher level of heat stability and an increased tolerance toward acidic pHs compared with the free keratinase. During a continuous reaction at 50^{0}C, the immobilized keratinase retained 40% of the original enzyme activity after 7 days. The immobilized keratinase exhibits improved stability, thereby increasing its potential for use in numerous applications.

Carbonized chicken feather fibers which can hold vast amounts of hydrogen have now been made (Wool, 2007). Chicken feather fibers are mostly made of keratin, a natural protein that forms strong, hollow tubes. When heated, the protein creates cross links, which strengthen its structure, and it also becomes more porous, increasing its surface area. The result is carbonized chicken feather fibers, which can absorb as much or perhaps more hydrogen than carbon nanotubes or metal hydrides, two other materials being studied for their hydrogen storage potential. They are also cheap. The project goal is to develop new low cost hydrogen storage substrates from the waste material chicken feathers. The results show that carbonized chicken feathers have the potential to meet the department of environment requirements for H_2 storage of 81 grams H_2 per litre in 2015 and are competitive with carbon nanotubes and metal hydrides at a tiny fraction of the cost. When keratin based chicken feathers are heat treated by a controlled pyrolysis process, hollow carbon microtubes are formed with nanoporous walls. Their specific surface area increases up to 450m^2/g by the formation of fractals and micropores thus enabling more hydrogen adsorption than the raw, untreated feather fibers.

According to the USDA / Agricultural Research Service (ARS) (2005) scientists have developed a method to turn chicken feathers into plastic products with the aim of bringing technology closer to the marketplace. ARS chemist Walter Schmidt developed the technology to clean feathers and separate them into chopped fibers and quill pieces. Now Schmidt and fellow ARS chemist Justin Barone have developed and applied for a patent for a process to convert cleaned and chopped feather material into plastic products on a laboratory scale. According to Schmidt and Barone (2004), the material is made on traditional plastics processing equipment using chopped chicken feathers and other easily obtainable, naturally derived materials. The feather-derived plastic can be molded just like any other plastic and has properties very similar to commodity plastics such as polyethylene and polypropylene. This makes the feather-derived plastic a unique material for packaging or any other application where high strength and biodegradability are desired. Previous research by Schmidt and Barone (2004) found that feather fiber could be added into currently used plastics to make composites. The fibers strengthen the plastic components, and reduce the weight of the material. Currently, the additives and fillers used in plastics by the automobile industry, for example, add significant weight to car parts. Using feather fiber is a viable alternative to these additives.

Seedling flower pots made from feathers instead of peat moss can be purchased commercially. Product development research may be the pre-requisite to finding increasingly valuable uses for feathers that utilize a larger fraction of the quantity of the renewable feather fiber supply presently being generated. Two characteristics of feather fiber that make it unique are its molecular order and its morphological order. The fiber is both highly microcrystalline and very durable, i.e., resistant to both mechanical and thermal stress. The best processes that incorporate feathers into value-added products alter its micro-/macro-scopic morphology but preserve much of its desirable original molecular properties.

Inspired by the embedment of emission species in synthetic photonic crystals to display novel optical properties, the natural photonic crystals within peacock feathers are chosen as the matrix to embed ZnO nanoparticles through an *in situ* approach. Peacock feathers function as the supporting substrate and provide reactive sites for the *in situ* synthesis of hexagonal ZnO nanoparticles (Han, 2008). Herein, ZnO nanoparticles exhibit photoluminescence in the visible range and are supposed to be tailored by the peacock feather, having potential applications in optoelectronics and optical communications.

Film, fibre, foam and adhesive materials have been produced from soluble S-sulfonated keratins. Once formed, the films, fibres, foams or adhesives are treated to modify the properties of the materials, in particular to improve the wet strength of the materials. Treatments used include removal of the S-sulfonate group by treatment with a reducing agent, treatment with an acid or treatment with a common protein crosslinking agent or treatment with a reduced form of keratin or keratin protein. The films are made by solvent casting a solution of S-sulfonated keratin proteins, the foam made by freeze-drying a solution of S-sulfonated keratin proteins and the fibres made by extruding a solution of a S-sulfonated keratin protein.

Feathers have also been made into Shuttlecock with luminescent means. It is one object of the invention to provide a shuttlecock which has luminescent means that produces a brilliant bluish luminescence by means of a chemical reaction. It is another object of the present invention to provide a shuttlecock with luminescent means which has a replaceable base that can be replaced after the chemical reaction is over. According to one aspect of the present invention, the shuttlecock comprises a base defining a water-tight space, a feathers unit detachably fastened to the base, an alkaline solution filled in the water-tight space, and a film-covered luminol ball disposed in the alkaline solution, wherein the luminol of the luminol ball is activated by the alkaline solution to produce a brilliant bluish luminescence when the luminol ball is broken by an external force being applied to the base. According to another aspect of the present invention, the feathers unit comprises a front coupling neck and an outside annular groove around the periphery of the front coupling neck; the base comprises a cap-like inner shell snuggly receiving the front coupling neck of the feathers unit, the cap-like inner shell having an inside annular flange engaged with the outside annular groove of the front coupling neck of the feathers unit.

2.7 Degrading of Waste Feather

Feather contains the complex protein keratin which is a fibrous structural protein also found in hair, nails, hooves, wool, feathers and skin. A quarter of amino acids in keratin are cysteine, whose ability to form strong bridging (disulphide) bonds with other cysteine units accounts for keratin's great stability. Keratin does not dissolve in cold or hot water and does not easily undergo proteolysis (Schrooyen, 1999). This makes it very difficult for feather to degrade hence its classification as being semi-biodegradable. However attempts are being made to make it easier for waste feathers to undergo biodegradation. Lateef *et al.* (2009) has isolated a local strain of *Bacillus cereus* LAU 08 from a chicken-feather disposal site in Ogbomoso, Southwest Nigeria for the production of keratinase to degrade feather keratin. . Production of keratinase was induced using three sources of keratin, namely: hooves, horn, and feather, at a growth temperature of 37 °C. In each case, high titers were recorded for both keratinolytic and proteolytic activities. Maximum enzyme activities were obtained within 24–96 h of cultivation, depending on the keratin substrate used and the activity under study. While maximum keratinolytic activities of 67.9, 63.1, and 51.7 U ml^{-1} were obtained using enzymes induced by hooves, horn, and feather, respectively, proteolytic activities of 11 860, 820, and 126 U ml^{-1} were obtained using enzymes induced by feather, hooves, and horn, respectively. The optimal conditions for the keratinolytic activity were determined to be pH 7.0 and temperature of 50 °C; however, the enzyme displayed more than 50% activities within the broad range of pH 7–9 and temperature of 40–70 °C. In addition, the isolate was able to completely degrade a whole chicken feather within a period of 7 days at room temperature (30 ± 2 °C). *B. cereus* LAU 08 is therefore a promising strain for the management of chicken feather waste through biotechnological processes.

2.8 WEED MANAGEMENT

A weed is any plant growing where it is not wanted, particularly where man is attempting to grow something else (Isely, 1960). In essence, even corn may be considered as weed if it grows along a highway shoulder, yet it is an important crop plant. Grass is a valuable plant for lawns and sports fields, yet it is a noxious weed in cultivated farmlands (Fogg, 1945).

Generally, there are many plants which usually grow where they are not wanted, have no economic value and usually interfere with the production of cultivated crops or with the welfare of livestock. These plants are always considered as weeds.

Weeds in general usually possess a number of specific attributes which render their success possible and contribute to their ability to persist in spite of man's efforts to stop their growth. Some of these attributes are:

1. Perennial Underground Roots or Stems – weeds that possess these structures will persist from year to year even if their seed production is prevented. The underground part will spread rapidly in all directions, sending up aerial stem buds at regular intervals. Furthermore, cultivation procedures may help spread pieces of such roots from a limited patch over much of the field, thus greatly augmenting the weed infestation. Example is the creeping roots of Canadian thistle (*Cirsium*).
2. Abundant Seed Production – many weeds are capable of producing literally thousands of seeds which are easily dispersed over a large expanse of land. Example is pigweed (*Amaranthus*).
3. Long-Lived Seeds – Seeds of many weeds may retain their viability in the soil for 10-50 years (Ahlgren *et al*. 1951). Examples are pigweed *(Amaranthus)* and primrose *(Oenothera)*.
4. Rapid Growth – Weeds are frequently capable of growing to maturity and setting seed within a very short period of time (30-60 days). Hence such weeds produce their seeds before adequate control measures can be taken. Example is foxtail *(Setaria)*.
5. Competitive Ability – Many weeds can overtake and retard crop plants even though the latter have had a head start. Thus weeds are often successful in out-competing crops for light and soil nutrients.
6. Unpalatability to Livestock – Frequently weeds which are successful are distasteful or poisonous to animals, or are protected by spines and similar structures. They are thus free to reproduce and spread unimpeded by normal grazing. Example is Canadian thistle *(Cirsium)*.

The adverse effects of weeds on crop production and ultimately on the economy is as great as the losses caused by insect injury to crops and plant diseases combined (Isely, 1960). Such losses resulting from weed infestation are not as striking as those due to diseases and insect outbreaks hence are often taken for granted. Weeds reduce crop yield due to their competitive effects, hence reduce agricultural income. Studies on weed control in sorghum showed that with moderate rainfall, one weed per two linear feet of row, reduced yield 40 percent (Philips, 1958). Some weeds have been found to have higher water requirement than crops. Example is the Cockleburs (*Xanthium*). Some other weeds have high mineral requirements. Example is the common mustard (*Brassica*) which requires twice as much nitrogen, twice as much phosphorus and four times as much potash.

Weed control measures whereby weeds are maintained at 'moderate' infestation levels cost millions of dollars every year. Much of crop cultivation would not be necessary if not for weeds. Chemical control measures, though rapidly gaining grounds, are quite expensive. The persistence of the herbicides and their adverse environmental implications on the soil and ground water is also of great importance.

Apart from their effect on total crop yield, weeds serve as hosts for insect and disease pests, thereby assisting in the reduction of quality of crops by the insects and pests.

Certain weeds are poisonous to man and animals, causing hat fever and so on. Some other weeds like the quackgrass, release poisonous substances into the soil (Dunham *et al.*, 1956). Weeds interfere with telephone lines, cause obstructions to power lines; they reduce vision on roads and reduce aesthetics environmentally. Economically, weeds lead to increase in the cost of agricultural labour and equipment.

However, some beneficial effects of weeds include the prevention of wind and water erosion, and they provide habitation for diverse insects and animals.

The need for weed control originated from the adverse effects of weeds on agriculture and crop production. Weeds compete with crop plants for light, water and soil nutrients thereby reducing yield of crops. The cheapest way to control weeds is not to have them in the first place. Most of the weeds are introduced one way or the other through weed seeds by various means including agricultural products and equipment. Hence the avoidance of new infestations from such sources is the cheapest weed control measure. To achieve this weed prevention technique, seed should be purchased from high quality seed processing and storage facilities to ensure seed quality. The I.A.R.&T. grains store at Apata, Ibadan, is a good example. If seeds are purchased from neighbourhood farmers, such seeds should be examined and custom-cleaned and tested for noxious weeds and total weed seed content before planting.

Various methods available for weed control can be grouped as follows:

1. Mechanical Methods – These include seed bed preparation to reduce weed seed populations in the upper soil layer. It is carried out by plowing and harrowing. Other mechanical means are band operations such as hoeing and hand removal of surviving weeds. This method involving the hand is still the widely used worldwide in the production of more than half the total production of food.
2. Cultural/ Cropping Methods – This involves the use of strong germinating seeds as against the use of poor seeds. The strong seeds will give the crop a vigorous head start against the weeds and compete better for soil nutrients than the weeds. The use of smother crops which prevent weeds from getting enough air falls under this method.
3. Burning – This has been used to destroy weeds by many people, but its attendant environmental pollution is discouraging the method. The method contributes easily to the green house gases which are adversely contributing to global warming.
4. Biological Methods – This involves the encouragement of certain pests or parasites of these weeds. This method has however presented other challenges such as relationship of the pest with the plant which might also be attacked. The introduction of mulching film prepared from waste feathers as weed control measure falls under the biological control methods.
5. Chemical Methods – This is the use of weed killer chemicals known as herbicides. Various herbicides available are classified based on their formulation, manner of application, manner of killing and their degree of selectivity. Some herbicides are poisonous to all vegetation, hence when applied at proper dosages will provide a complete kill. Examples are chlorates and borax compounds. Other herbicides are selective in their action. They are capable of killing some kinds of plants but will leave others relatively unharmed. The selective or non-selective natures of these herbicides are better considered quantitatively rather than qualitatively. For a herbicide to act selectively is dependent on proper use of the right dosage, formulation, right timing and manner of application. The dangers of herbicide residues on human food have been the major concern in the use of herbicides as

weed control chemicals. Also herbicide residues on forage plants which act as food for animals should be avoided. Animals should not be allowed to graze in pastures unless after two weeks of spraying with contact herbicides.

Plant parts intended for human consumption should never be exposed to weed sprays. The most appropriate weed control method used therefore, will ultimately depend on the scale of farming, legislation guiding use of herbicides and cost of the weed control measure. The aim of this project is to produce a cheap weed control mulching film from waste feathers and make it applicable for many crops.

2.9 MULCHING AS A MEANS OF WEED CONTROL

According to the American Society for Horticultural Science, in 1999 more than 30 million acres of agricultural land worldwide were covered with plastic mulch, and those numbers have been increasing significantly since then. With the recent trend toward "going green", researchers are seeking environmentally friendlier alternatives to conventional plastic mulch.

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.

Ngouajio *et al*. (2008) 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. Breakdown of white mulch occurred early and exposed the bed for weed growth, creating competition for nutrients between weeds and tomato. As the weeds grew, they tore the mulch, leading to further degradation. Furthermore, the weeds hosted a large insect population that reduced the quality of the tomato. Weed control levels for both thicknesses of the black biodegradable mulch were more than 90%. Black biodegradable mulch performed well in the field, producing tomato crops similar to conventional mulch during both years of the study.

Mulching is the practice of placing a loose surface onto the surface of soil in flower or vegetable garden in order to protect, insulate and beautify the area (Durham *et al*., 1956).

This loose covering is called mulch and it can be either of an organic or inorganic variety. Examples of mulches include compost, stone and grass clippings. Every gardener should understand the many benefits of mulching the soil in their garden.
Mulch is a protective material for the soil which helps to reduce weed growth and also keeps the soil cool and moist. The mulch can also help to prevent soil erosion thereby helping the soil to retain the much need soil nutrients. In the winter mulch helps protect the plant from damage due to freezing and thawing.

Benefits of Mulching include the prevention of soil erosion. Soil erosion happens when winds or water slowly wears away the surface of soil and remove it. Mulching your soil will prevent this as there is now a protective, replaceable layer that comes between the surface of the soil and the forces of nature above it. Another benefit is that mulching insulates the soil in winter. The harsh temperatures of winter can be unkind. Mulching the soil in winter will insulate the soil preventing it from repeated patterns of freezing and thawing and will insulate plant roots. It prevents heaving (buckling upward) of soil in spring. Mulch should be applied to the soil when it has frozen and removed in spring only when there is no danger of further frosts. Winter-mulched soil thaws out more quickly in the spring.
Mulching also cools down the soil in summer. A layer of mulch in summer protects the soil beneath from the extreme heats of summer and reduces the need for constant watering i.e. water retention is improved. Mulching helps against soil compaction. The layer of mulch acts as a buffer or extra layer between entities that can cause compaction on the soil below e.g. people, equipment, and heavy rains. Mulch applied to the plant bed can make it look more complete and attractive. This varies from mulch to mulch as some are more attractive and natural looking than others.
One of the more useful benefits of mulching is in weed prevention. While the mulch itself will not stop weeds from germinating, it serves to act as a barrier between the weeds and the outside world above. When a weed reaches the mulch layer it will not be able to break above it and it will eventually die back. Some mulches perform this weed prevention feature better than others. Depth of mulch is also a contributing factor. Care should be taken however when selecting mulches as some mulches like grass clippings and straw may actually contain weed seeds. Finally, a layer of mulch reduces the chances of fruit and vegetables getting dirty from splashes from the soil below.

The technique of applying mulch has been employed as a means of weed control over the years. Many different materials can make good mulches. For weed control and moisture retention, the type of mulch used depends on the cost and the need to replenish the mulch over time. Hence the factors to be considered in the choice of the type of mulch to be selected are:

1. **Soil pH suitability** - Some mulches like bark mulch and pine needle mulch can affect the pH value of soil so they are best used on soils containing acid-loving plants.
2. **Removal in spring** - Certain mulches need to be removed in spring because they can smother emerging plants. Examples include stone mulch and bark chips.
3. Cost - Is cost a limiting factor in your choice of mulches? If so you can find your mulch for free if you choose certain types. If you keep a compost heap then you will have compost for mulching. Other free mulches (if you have the sources) are pine needles and grass clippings.
4. Appearance - If one cares about how the bed will look when the mulch is applied then appearance becomes an important factor. Each mulch adds a different look and depending on the design of your garden you may want to choose a mulch that matches it in colour and texture.
5. **Penetration by water and air** - Some mulches are better at allowing water and air to pass through them than others. This may be important depending on a plant's watering requirements.
6. Addition of nutrients to the soil - Organic mulches add nutrients back into the soil when they decompose. The nutrient types and their amounts added back into the soil depend on the mulch and it varies quite a bit. Using compost as a mulch guarantees plenty of nutrients for your plants.

A Mulch can either be organic or inorganic in nature

Organic Mulch: This type of mulch once used to be living material and as such will decompose over time. During their decomposition vital nutrients will be added back into your soil. However you may want to avoid using organic mulches if you have rodent problems. Some common organic mulches are

1. Wood Chips and Bark

Wood chips and bark are among the mulches most commonly used in landscaping. Woods such as cedar, cypress, and pine are popular because they are durable, look good, and smell great. Larger pieces of wood or bark don't break down as quickly as shredded wood mulches but may float away in heavy rain. Shredded mulch is especially useful on slopes or paths, because it doesn't easily wash away. Wood chip and bark mulches can be purchased at garden centers and sometimes it can be obtained free of charge. Road workers generally shred the overhanging branches they remove from roadsides into coarse mulch, and often they will give the mulch away. There is always some possibility that the original trees were diseased, but many gardeners have used this free mulch for years with no difficulties.

2. Straw

Because it's not very ornamental, straw is best used in vegetable gardens or over newly seeded lawns. It works well in vegetable gardens because it improves the soil as it decays, and makes walking around the garden easier in the meantime. Straw is also a good material to use as winter mulch for perennials. Be careful not to use hay or straw that contains too much weed seed or there will be a garden full of weeds in the spring. It should be applied to a depth of 6 - 8 inches.

3. Pine Needles

A two-inch layer of pine needles makes excellent, attractive mulch for acid-loving trees and shrubs. It is cheap, looks great and allows water to pass through freely to the soil below. It decomposes quite slowly however and should be applied to a depth of 1 - 1.5 inches.

4. Cocoa Bean Hulls

Many gardeners use cocoa bean hulls as a mulch. They are a beautiful color and have an attractive fragrance. However, cocoa bean mulch should be avoided if pets are allowed in the area. It contains theobromine, which is highly toxic to dogs and cats. Many dogs are attracted to cocoa bean hulls, and the result can be deadly.

5. Compost or Shredded leaves

These are excellent types of mulch for gardens because they add nutrients to the soil as they break down. They're also readily available. After the leaves decompose, dig them into the soil and add a new layer on top. Grass clippings can be left on your lawn or used to mulch vegetable or flower gardens. However, one shouldn't use clippings from lawns that were treated with herbicides.

6. Newspaper - Provides great weed control and is readily available. It is advisable to apply another type of mulch on top to keep the newspaper in place.

Inorganic Mulch

Inorganic mulches are inert materials that have not originated from living material. Sometimes inorganic and organic mulches are used in conjunction with one another. For example a geotextile (inorganic mulch) may be covered and held in place by bark chips (organic mulch). Some common inorganic mulches are:

1. Rocks/Stone - Looks great and provides great insulation. If removal in spring is a factor in your choice of mulch avoid using stone. Degrades very, very slowly. Landscape rocks are available in many sizes, shapes and colors. Rocks don't do anything for the soil nutritionally, but a one- or two-inch layer will help suppress weeds. Rocks are hard to get rid of once you have them, so they are best used for permanent plantings. Rocks reflect solar radiation and can create a hot landscape during the summer months. They look good in desert or xeriscape gardens. Should be applied to a depth of 2 - 4 inches.
2. Plastic - Does not decompose so it does not add anything into the soil. Acts as a great weed control and is easily laid. Must be perforated to allow water to pass through. Black plastic does a good job of warming soil up in the spring, so you can get an early start on planting tomatoes and other vegetables that like warm soil. Apply in a thickness of 1 - 6 mm.
3. Geotextile/Landscape Fabric - Expensive blanket-like synthetic fiber that provides great weed control and allows for water penetration. Materials woven of fabric, plastic or paper are available at garden centers and often types of mulch used by professional landscapers. These materials are treated to resist decomposition, but unlike black plastic, the fabrics allow water and air to move through them. Landscape fabric needs to be fastened down with pins so it will not be pushed up by perennial weeds. You will want to cover the fabric with a few inches of another mulching material such as wood chips, both to hide the fabric and because it is possible for weeds to sprout up on top of the fabric. Landscape fabric is best used for more permanent plantings because it is more difficult to transplant plants that are

growing in fabric. Almost always used in conjunction with a cover mulch (e.g. bark chips). Apply in a single layer.

The mulch to be produced from waste feathers in this project is organic in nature and hence will possess the virtues of organic mulch which includes infusion of nutrients into the soil apart from weed control and prevention of soil erosion. Nutrients in the soil must reach certain level for the soil to be considered suitable enough to support plant growth. Particularly the nitrogen, phosphorus and potassium levels in the soil can be considered as low, medium or high according to the soil nutrient ratio (Uponi and Adeoye, 2000).

Table 2: Soil Nutrient rating

Nutrient	Low value	Medium	High
N	<0.10%	0.10-0.15%	>0.15%
P	<10ppm	10-20ppm	>20ppm
K	<0.15meq/100g soil	0.15-0.25	>0.25meq/100g soil

Source: Uponi and Adeoye, 2000

CHAPTER THREE

METHODOLOGY

3.0 Project Design

This project work is experimental in nature and laboratory-based, with six treatments of four replicates each arranged in a completely randomized design. It was intended to be carried out first on a laboratory scale to determine the efficiency of the mulching film produced from waste feather in weed control and improved crop yield. This laboratory scale will be used to assess the feasibility of a large scale production and use of the waste feather mulching film in weed control and crop production.

3.1 Project Site

The Institute of Agriculture Research & Training (I.A.R. &T), Apata, was selected as the project site. This is due to the easy availability of the screen house facilities, laboratories, test crop seeds and closeness to the Zartech Industries within the same local government area.

3.2 Sample Collection

Materials and samples required for this project work were sourced from locations within the southwest area of Ibadan having two large poultry farms that turn out large quantities of waste feathers.

i. Waste Feather Collection

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 began full farm operations (starting with poultry farming) in 1984. It is occupying an area of over 75 Hectares of land. Over the years Zartech Farms has diversified extensively into fishery farming, livestock farming, animal feed production, horticulture and floriculture. Also it has established more farms to cater for the increasing demands for her products. Zartech currently owns and maintains several branches, farms and direct sales outlets nationwide. The industry is one of the largest poultry industries in the Southwest of Nigeria slaughtering over 20,000 birds per day, hence generating tones of waste feathers. The waste feathers were collected wet and unclean as they were being washed out of the production line at the slaughter house. Plate 4 shows the collection of wet waste feathers from Zartech Industries, Oluyole estate, Ibadan.

A second poultry industry also in Oluyole Estate, Bronco Farms, slaughter about 10,000 birds daily and also produces enormous amount of waste feather. Zartech industry was however selected due to the larger production capacity. Between these two poultry farms alone, over 30000 birds are slaughtered daily generating tones of waste feathers.

2. Soil Sample Collection:

Two 20 litre buckets full of humus (top) soil sample was collected from the arable field of Institute of Agricultural Research and Training (I.A.R and T.), Apata, Ibadan, using a rake to clear the surface debris, then a shovel and hoe to pack the soil into the container. The soil sample was collected around 10.00AM before the sun was too hot to prevent excessive loss of soil humidity. The soil sample collected was sieved through a 3mm pore-sized sieve to allow easy penetration of seedling shoots and roots in the soil.

A chemical analysis was carried out on the soil sample to determine its nutrient status, namely nitrogen, potassium and phosphorus. This helps to determine the fertility rating of the soil before introducing the test seeds.

3. Experimental Seeds Collection

To effectively monitor the ability of the waste feather mulching film in controlling weed growth at a laboratory scale, it is important to use a cereal crop which germinates quickly with measurable shoot and leaves. Maize crop was therefore selected due to its availability and being a very common crop in the southwest of Ibadan. Maize seeds were purchased from Grain Storage at I.A.R. & T., Apata, Ibadan. The Downey Mildew Resistance - Early Streak Resistance - Yellow (DMR-ESR-Y) seeds were purchased for use. These were selected because they germinate quickly with good yield. Plate 7 shows the seeds of DMR-ESR-Y maize used.

4. Weed Sample Collection

It was necessary to select a vegetable to use as "weeds" against the maize test crop. As a result, seeds of *Corchorus olitorius* 'Ewedu' Seeds were selected for use. 'Ewedu' seeds were selected to be used as weeds because the seeds are tiny and can be sprinkled on the soil surface at random and also because they germinate quickly to allow easy monitoring and assessment. The seeds were also purchased from the Genetic Storage at I.A.R. & T., Apata, Ibadan. Plate 8 shows the seeds of *Chorchorus olitorius* ("Ewedu").

3.3 Sample Preparation

The research laboratory of Federal College of Agriculture within the I.A.R & T. campus was selected for use due to availability of space and necessary equipment, apparatus and chemicals for use in the research. All the samples collected were moved to the laboratory and the seeds were prepared for planting. The waste feathers collected were also subjected to necessary preparations before use.

1. Soil Preparation

Having sieved the soil sample, a chemical analysis was carried out on the sample to determine some soil nutrient status, namely nitrogen, phosphorus and potassium. This will help to determine the fertility status of the soil sample collected and its suitability for the crop germination.

One kilogramme of soil was measured into each of twenty four plastic pots to be used to plant the test crop.

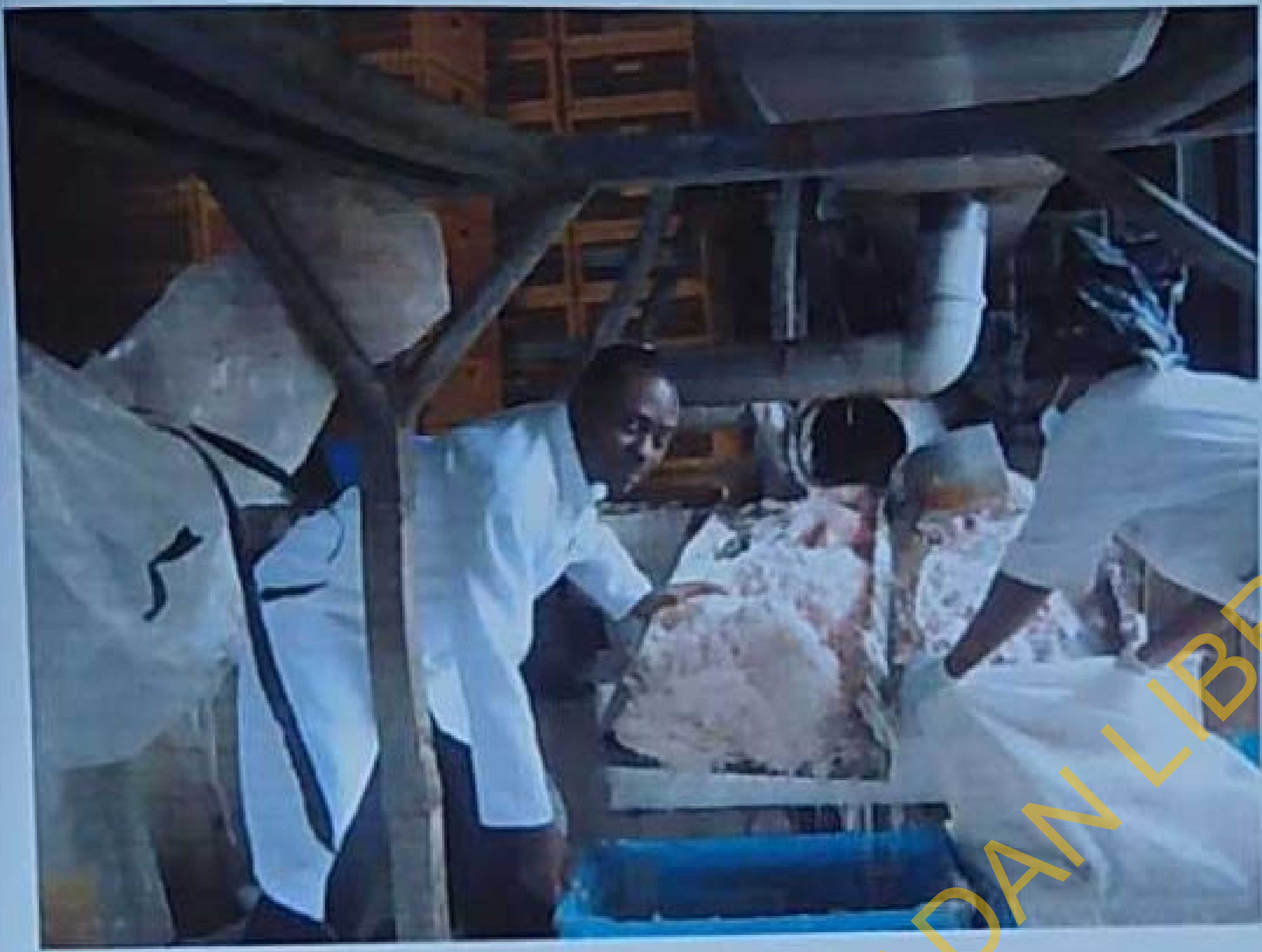

Plate 4: Researcher Collecting Waste Feathers from Zartech Industries, Oluyole Estate, Ibadan.

2. Pot Preparation: The experiment consists of two factors.

Factor 1 comprised of the processed feathers (mulch) with two options F_1 for "absent" and F_2 for "present".

Factor 2 comprised of the crop (maize) and weed ("ewedu") with three options C_1 (maize alone), C_2 ("ewedu" alone) and C_3 (maize with "ewedu").

The two factors and the options are presented on a 2 x 3 table (Table 3). Hence there are 6 treatments replicated 4 times each, giving a total of 24 treatments in a completely randomized design.

The 24 plastic pots with capacity of 1.5 litres were obtained and divided into six groups of four replicates each. The pots had diameter of 14cm. One kilogramme of treated soil was measured into each pot and the soil had a depth of about 11.5cm inside each pot.

The pots were labeled and seeds were planted as follows:

Group A pots were labeled as Maize alone without mulch

Group B pots were labeled as "Ewedu" alone without mulch

Group C pots were labeled as Maize and "Ewedu" without mulch

Group D pots were labeled as Maize alone with mulch application

Group E pots were labeled as "Ewedu" alone with mulch application

Group F pots were labeled as Maize and "ewedu" with mulch application.

Groups A, B and C pots had the same seeds planted in them just like groups D, E and F respectively, except that groups D, E and F pots were covered with feather mulch on the third day while groups A, B and C pots had no mulch applied.

Hence, Groups A, B and C were the controls while Groups D, E and F were the test groups.

Table 3: Preparation of pots into groups

	C_1 (maize)	C_2 ("ewedu")*	C_3 (maize and "ewedu")
F_1 (no feather mulch)	F_1C_1 **Group A** (maize without mulch)	F_1C_2 **Group B** ("ewedu" without mulch)	F_1C_3 **Group C** (maize and "ewedu" without mulch)
F_2 (with feather mulch)	F_2C_1 **Group D** (maize with mulch)	F_2C_2 **Group E** ("ewedu" with mulch)	F_2C_3 **Group F** (maize and "ewedu" with mulch)

*"ewedu" is *Corchorus olitorius*

Plate 5: Groups A, B and C Pots (without mulch)

Plate 6: Groups D, E and F Pots (with mulch

3. Seeds Planting:

The seeds were planted inside the soil in the pots as were labeled.

Group A pots: Maize seeds were planted alone in the group A pots. 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.

Group B pots: "Ewedu" seeds were planted alone in the group B pots. Due to the very tiny sizes of the seeds and the need to allow equal treatments all through, the tiny "Ewedu" seeds were weighed on an electronic balance. Equal mass (0.96g) of "ewedu" seeds were sprinkled on and slightly mixed with the soil.

Group C pots: Maize seeds were planted as in group A, but "ewedu" seeds were sprinkled over and mixed slightly with the soil on the third day as soon as maize germinated. All "ewedu" seeds were planted on the same day.

Plate 5 shows the pots in Groups A, B and C after germination.

Group D pots: Maize seeds were planted alone just like group A pots, but the soil surface was covered with feather mulch three days later as soon as the maize germinated.

Group E pots: "ewedu" seeds were planted alone just like in group B pots, but the soil surface was covered with feather mulch on day three immediately the "ewedu" seeds were planted.

Group F pots: Maize seeds were planted and "ewedu" seeds sprinkled over the soil three days later just like in group C pots, but the soil surface was covered with feather mulch on day three as soon as the maize germinated.

Plate 6 shows the pots in groups D, E and F after germination and mulch application.

Plate 7: Seeds of DMR-ESR-Y Maize purchased from Grains Storage of Institute of Agricultural Research and Training, Apata, Ibadan.

Plate 8: Seeds of *Corchorus olitorius* ("Ewedu") purchased from Grains Storage of Institute of Agricultural Research and Training, Apata, Ibadan.

3.4 Processing of Waste Feathers

1. Feather Density: the density of feather fiber was determined by displacing a known volume and weight of ethanol with an equivalent amount of fiber. This was done according to standards of analysis of chemicals.

2. 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, 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-featheredchickens. 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

$$WF = DW - WD$$

3. Extraction of Soluble Keratin from Feathers: Soluble keratin was extracted from feathers by reduction with ammonium sulphide solution. A total of 60 g of clean, dry and chopped feathers were mixed with 1.5 liters of 0.1M hot aqueous ammonium sulphide solution. The mixture was stirred continuously and maintained at 60°C and stirred for one hour. Undissolved feathers were separated from the dissolved keratin by filtering using a clean white cotton cloth. This gives about 59.5% keratin in the filtrate. After cooling the filtrate was tested for protein using the Biuret test.

3.5 Preparation of Feather Mulching Film: The feather mulching film was prepared in stages as shown in the flowchart below:

1. Pre-Treatment Stage: This involved washing the feathers in mild "omo" detergent prepared by dissolving 10 grammes of detergent in 1 litre of water. The detergent solution was used to remove traces of fat and dirt from the waste feathers, then properly rinsing in

water, then air-drying the feathers. Plate 10 shows the washed and dried waste feathers ready for grinding. Afterwards, the fibers were taken to the 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 grinded. A thirty horse-power grinding machine was used to grind the feather fibers into tiny fragments until almost powdered state was obtained. Plate 11 shows the waste feathers being ground in the machine while plate 12 shows the collection of ground waste feathers.

3. Mixing Feather with Glycerol: The mixing ratio for glycerol to feather-fibers was 1:3 by mass. Hence, 80g of the feather fiber was measured and placed in a large crucible, and then 27g 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 to act as a plasticizer in the mixture.

4. Making the Feather Film: The sticky feather-glyceral 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. Plate 13 shows the prepared feather mulch on an aluminium foil being exposed for air-drying while plate 14 shows a sample of the prepared feather mulch. 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 the 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. Plate 15 shows the application of the feather mulch on the soil surface.

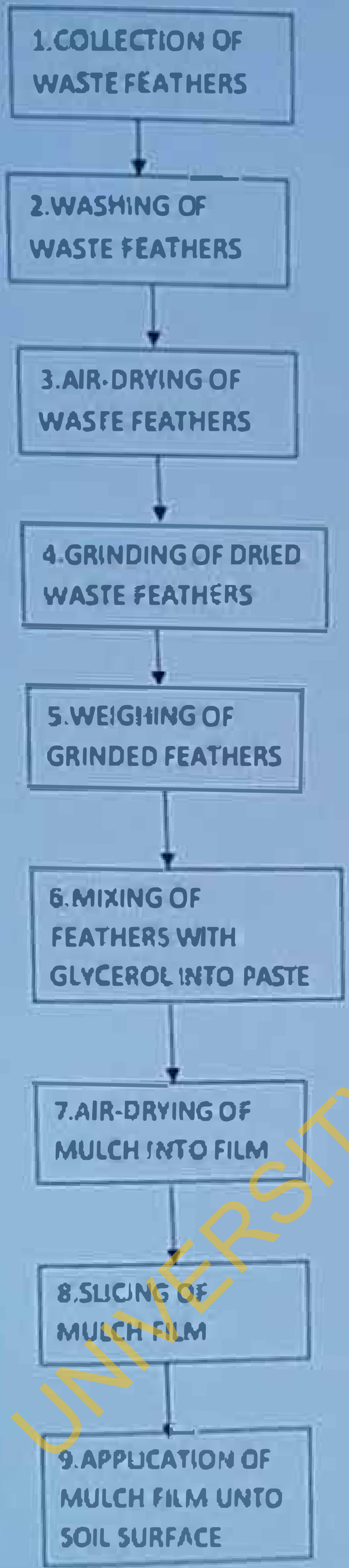

Plate 9: Flowchart showing the stages involved in Mulch Preparation.

Plate 10: Washed and Dried White Feathers

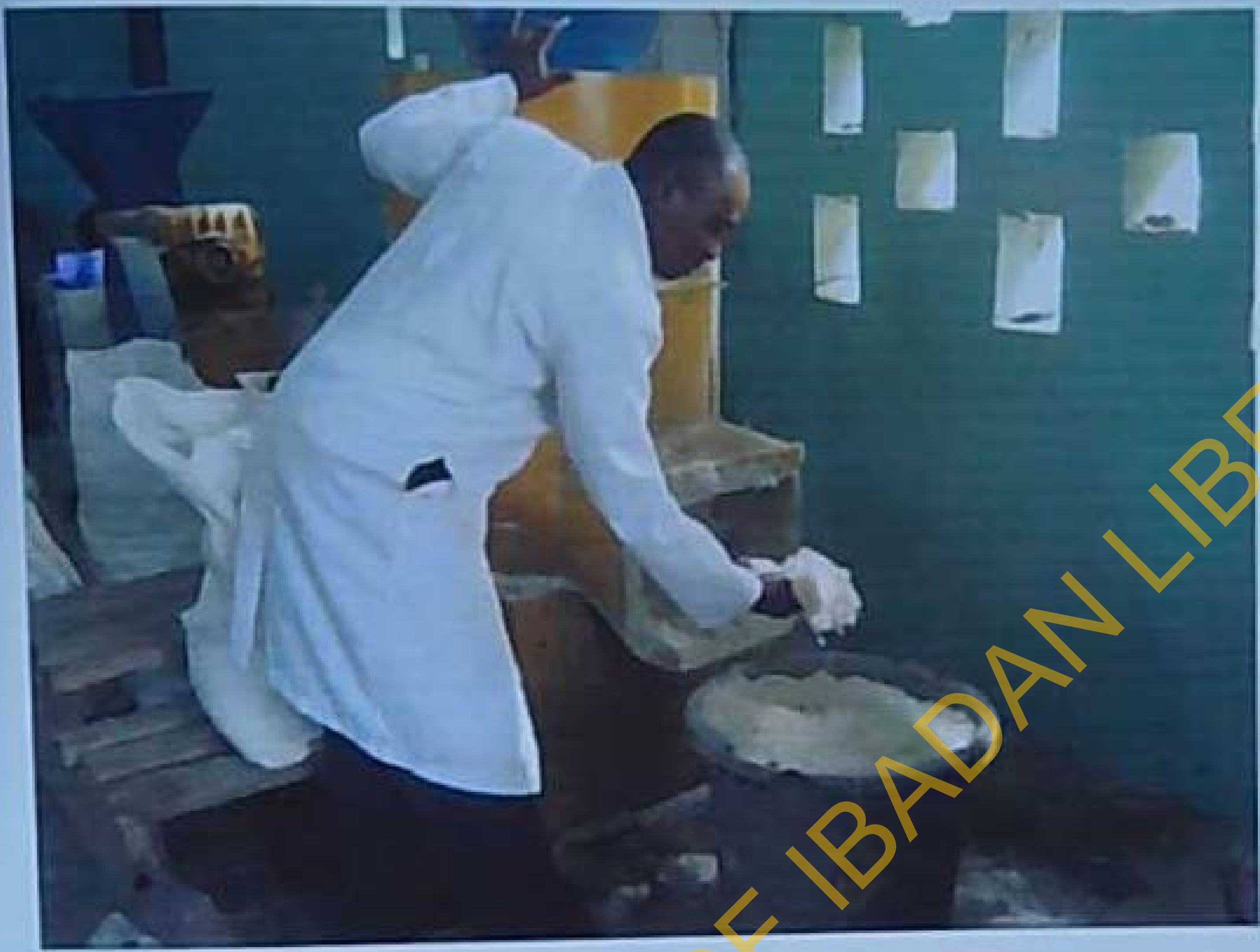

Plate 11: Grinding of dried feathers in a mill at Waste recycling Plant, Aleshinloye, Ibadan.

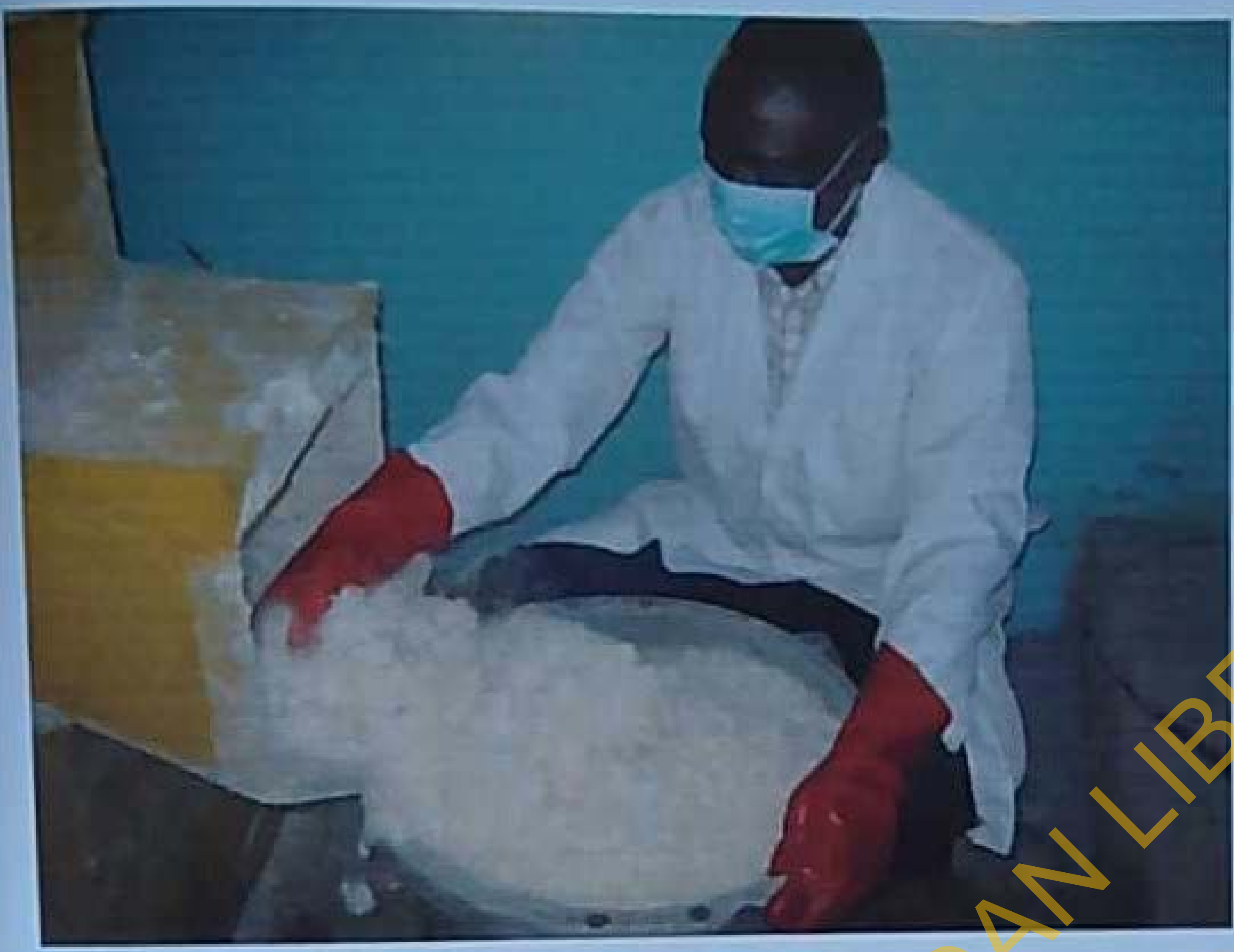

Plate 12: Collection of ground feathers

Plate 13: Prepared Feather Mulch on aluminium foil

Plate 14: Sample of Feather Mulch before application on soil

Plate 15: Application of feather mulch on soil surface after germination of maize crop

3.6 Chemical Analysis for Nutrients

Analysis was carried out on the soil sample and on the feathers to determine the amounts of various nutrients present.

1. Total Organic Carbon: The total organic carbon was determined as follows: Reagents used were $K_2Cr_2O_7$, Conc H_2SO_4 and 0.5N $FeSO_4.7H_2O$. One gramme of sample was measured into a 500ml Erlenmenyer flask and 10ml of 1N $K_2Cr_2O_7$ was added. The mixture was swirled gently followed by the addition of a mixture of 20ml conc. H_2SO_4, 300ml of distilled water and 25ml of 0.5N $FeSO_4$. The resulting solution was titrated against standard $KMnO_4$ from a burette using illumination from a bulb lamp. A colour change from deep green to purple signified the end point. This was repeated for the blank. The concentration of carbon in the sample was calculated as follows:

$$\text{True \% organic carbon} = \frac{N(T-B) \times 0.390}{W}$$

Where W = weight in grams of sample

T = volume of $KMnO_4$ used in titrating the sample

B = Volume of $KMnO_4$ used in titrating the blank

N = Normality of $KMnO_4$

2. Total Kjeldahl Nitrogen: Total nitrogen was determined using the Kjeldahl distillation and trimetric method and the result expressed in percentage (%). The reagents used are.

1. Boric acid 4% solution. Dissolve 40g Boric acid in 1 litre distilled water
2. Zinc granules
3. Sodium hydroxide solution 40%. Dissolve 400g NaOH pellets 1 distilled water, cool and make up to 1 litre mark with distilled water.
4. 0.2N HCl, standardized
5. Sulphuric acid, H_2SO_4 (S.G. 1.84)
6. Sodium Sulphate (anhydrous), and
7. Cupric Sulphate.

Analysis was done by weighing 0.5g of the sample into a 500ml Kjeldahl flask. Approximately 0.65g of cupric sulphate, 15g of anhydrous sodium sulphate and 25ml of conc sulphuric acid were added to the content of the flask. The flask contents were digested for at least 1 hour or until frothing stopped. After this, the sample was cooled and carefully transferred into a 500ml volumetric flask and madeup to the mark. About 100ml of the sample was pipette out of the 500ml flask into another Kjeldahl flask and 50ml of 40% NaOH was added, together with few drops of zinc granules plus 100ml of distilled water to reduce the risk of boiling off and cracking the flask. Into a 250ml Erlenmeyer flask, 100ml of 4% boric acid was added plus 3 drops of bromocresol green indicator. The Kjeldahl flask was connected to the distillation unit and distilled into the boric acid. Distillation continued until the solution turned dark- red. The volume of acid (VHCl) used was recorded. The concentration of total nitrogen in the sample was calculated as follows:

$$\% N = \frac{VHCl \times NHCl \times VT \times 100 \times 14}{Vs \times 100 \times w}$$

Where VHCl = volume of HCl used

NHCl = normality of HCl used

VT = total volume made up after digestion

w = weight of sample used

Vs = volume of sample used.

3. Phosphorus Content: Determination of total phosphorus in form of P_2O_5 was carried out spectrophotometrically using the molybdovanadate method according to Standard Methods (1980). The reagents used in the analysis were

1. Conc Nitric acid
2. Perchloric acid (70-72%)
3. Molybdovanadate reagent.

Fourty gramme (40g) of ammonium molybdate tetrahydrate was dissolved in 250ml of 70% perchloric acid. Ammonium molybdate solution was added gradually to the metavanadate solution while stirring. This was cooled and made up to 2 litres with water. Standard phosphorus (P_2O_5) was prepared by weighing 0.9588g of potassium dihydrogen phosphate (KH_2PO_4) after oven-drying at 105°C for 1 hour into a litre volumetric flask, dissolved in distilled water and made up to the mark. (1ml = 0.5mg P_2O_5). 40ml of this solution was pipetted into a 500ml volumetric flask and made up to the mark with distilled water thus giving a P_2O_5 concentration of 1ml = 0.04mg P_2O_5. Suitable proportions of this solution were taken: 0ml, 5ml, 10ml, 15ml, 20ml, 25ml, and the corresponding absorbance reading taken at 400nm with difference absorbance values respectively. A sample analysis was done by weighing 0.9g sample into a 250ml Erlenmeyer flask, 20ml conc nitric acid was added and boiled and allowed to cool before transferring quantitatively into a litre volumetric flask and 50ml distilled water plus 10ml of molybdovanadate reagent and made up to the flask. This was repeated for the blank and allowed to stand for 10 minutes before reading absorbance at 660nm. The concentration of P_2O_5 in the sample was calculated as follows:

$$\%P_2O_5 = \frac{Abs \times F \times 1000 \times 100}{5 \times 1000 \times W}$$

Where F = P_2O_5 factor obtained from calibration curve

Abs = Absorbance (Difference between absorbance reading of sample and absorbance reading of blank)

W = weight of sample used

$$\%P = \frac{\text{Mol. Weight of P} \times 2}{\text{Mol. Weight of } P_2O_5}$$

4. Potassium Content:

Determination of total potassium was done using hydrofluoric and perchloric acid digestion according to AOAC (Association of Official Analytical Chemists) methods of analysis. Reagents used in the analysis are:

1. Hydrofluoric acid (HF) 48%
2. Perchloric acid ($HClO_4$) 70-72%
3. Hydrochloric acid (HCl) 6M

Precisely 0.5g of sample was placed in 50ml crucible. Few drops of water were added to the sample to make it wet and then 5ml of HF and 5ml of $HClO_4$ were added. The crucible was then placed on a sand bath, and nine-tenths of the crucible was covered with a lid. The crucible was heated to 200-250°C and the contents were evaporated to dryness. The crucible heated on a hot plate for the solution to boil gently until the residue dissolved completely in HCl. It was then transferred to a 100ml volumetric flask and contents were made up to the appropriate volume. Total potassium was then determined

CHAPTER FOUR

RESULTS

4.0 This chapter presents the observations and results of the various analysis carried out on the chicken feathers, on the soil samples and also the results obtained from the greenhouse experiments using feather mulch and the test crops.

4.1 Characteristics of Soil used

1. The pH of Soil Sample: The soil sample showed a pH of 6.9. This pH was found to support the growth of the potted plants.

2. Some Nutrients in the Soil Sample: The result of the analysis of some required nutrients (NPK - nitrogen, phosphorus and potassium) in the soil sample is shown in Table 4. The soil contained 22.4g/Kg of carbon. 1.8g/Kg of nitrogen, 12.6mg/Kg of phosphorus and 62.4mg/Kg of potassium.

The various amounts of the soil nutrients in the soil sample is considered high enough to support the growth of the potted plants in this work according to the soil nutrient rating in Table 2.

4.2 Composition of Feathers

1. Density of Feather fibre: A density value of 8.9×10^{-4}kg/cm^3 was obtained.

2. Amount of some nutrients available in waste feather were analysed and the results obtained are shown in Table 5. The percentage of total nitrogen, phosphorus and potassium (NPK) in white and variegated feathers were obtained. White feathers were found to contain 14.11% N, 0.18% P and 0.6% K, while the variegated feathers 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) was probably due to the presence of the proteinous colour pigment melanin, which contains additional nitrogen.

Table 4: Characteristics of soil used in the experiments

Soil Nutrient	Amount in soil
Organic Carbon	22.4g/Kg
Total Kjeldahl Nitrogen	1.8g/Kg
Phosphorus	12.6mg/Kg
Potassium	62.4mg/kg

Table 5: Available Nutrients in waste feathers

Some Nutrients in feather	Amount found in White Feathers	Amount found in Variegated Feathers
Total Kjedahl Nitrogen %	14.11	16.46
Total Phosphorus %	0.18	0.13
Potassium %	0.6	0.83

4.3 Average Weight of Chicken:

By taking the live weights of ten samples of three species of chickens, result shows the average weights to be 1.805Kg, 1.79Kg and 3.26Kg for Broilers, Layers and Breeders species respectively as seen on table 6. These live weights show the variation in the mass of live chickens based on their species. Average Live Weight of breeders was found to be the highest (3.26Kg) compared to broilers (average of 1.805Kg) and layers (average of 1.79Kg).

4.4 Percentage by Mass of Feathers per Chicken:

Table 7 shows the results obtained for the determination 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 0.166Kg (8.52%) of feathers when compared with the total body mass.

Table 6: Average Weight of Chicken

Chicken Sample	Broiler (Kg)	Layer (Kg)	Breeder (Kg)
1	2.02	1.65	3.2
2	1.69	1.85	3.6
3	1.34	1.45	2.5
4	1.37	1.55	3.5
5	2.05	1.85	4.0
6	1.85	2.10	2.5
7	1.92	1.68	3.4
8	2.10	2.05	2.4
9	1.74	2.05	4.2
10	1.97	1.65	3.3
Mean Weight	1.805	1.79	3.26
Standard Deviation	0.27	0.23	0.63

Table 7: 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	[illegible]	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	

4.5 Effect of Mulch Application on Maize crop without "Ewedu" weeds:

Maize crop planted alone (without "ewedu" weeds) and no mulch application in Group A was compared with Group D having Mulch application.

Chart 1 shows the graphical presentation comparing the length of leaves in Groups A and Group D. The chart shows an increase in length of leaves of maize in group D (with mulch) over those in group A (without mulch).

Appendices 1 and 2 show details of measurements of length of leaves for Groups A and D respectively.

Appendix 1 shows Length of leaves of maize planted alone but without mulch in Group A increased steadily up to a mean length of 35.9cm ±1.21 by day 28.

Appendix 2 shows the length of leaves of maize in Group D planted alone and mulched also showed steady increase but much more than group A. By day 28 Group D maize showed mean length of leaves of 38.9cm ± 2.1. The increase in length of leaves of Group D over control Group A was significant ($P < 0.05$) by day 20. Group A mean was 25.6cm ±1.6. and Group D mean was 27.8cm ± 2.2).

Tables 8 and 9 show length of shoots for Groups A and D respectively.

Table 8 shows length of shoots of maize planted alone but without mulch in Group A increased steadily up to a mean length of 12.7cm ±0.21 by day 28.

Table 9 shows the length of shoots of maize in Group D planted alone and mulched also showed steady increase but much more than group A. By day 28 Group D maize showed mean length of shoots of 14.4cm ± 0.35.

The increase in length of shoots of Group D 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 3.3cm ± 0.08 for Group D.

Appendix 3 shows the result of the test of significance for the length of leaves and length of shoots for both groups A and D

Results from these tables and chart show that maize with mulch had longer leaves and shoots than maize without mulch.

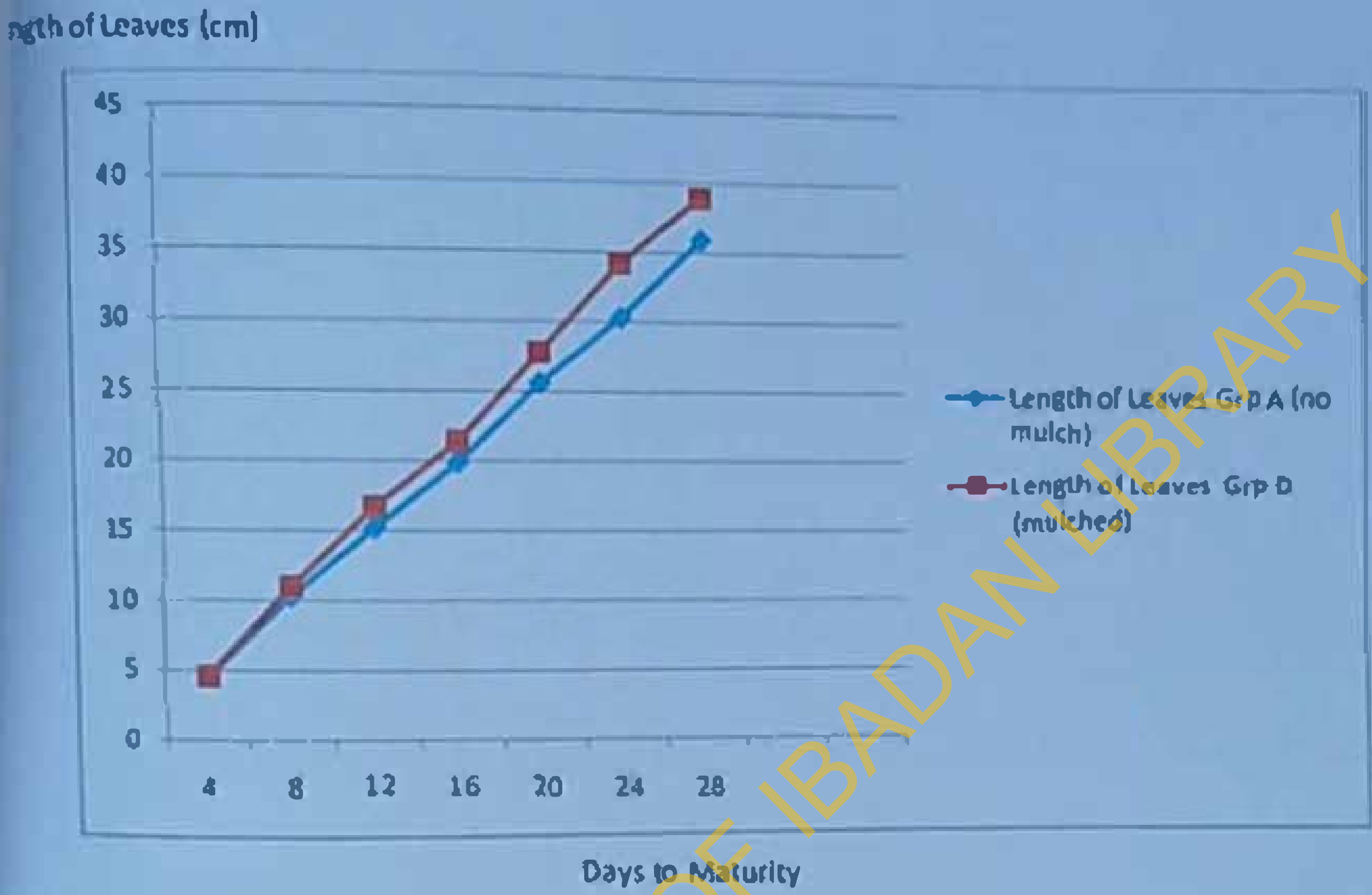

Chart 1. Graph comparing the Length of Maize Leaves (with Mulch and without Mulch)

Table 8: Length of shoots of maize planted alone in Group A

DAY	POT 1		POT 2		POT 3		POT 4		Mean Length	Standard deviation
	Sht 1 (cm)	Sht 2 (cm)	Sht 1 (cm)	Sht 2 (cm)	Sht 1 (cm)	Sht 2 (cm)	Sht 1 (cm)	Sht 2 (cm)		
3	1.0	0.9	1.0	0.8	0.8	0..9	1.0	1.0	0.9	0.10
4	1.6	1.5	1.5	1.5	1.6	1.5	1.5	1.6	1.5	0.05
6	2.1	2.0	2.0	1.9	2.0	2.0	2.1	2.1	2.0	0.07
8	3.2	3.0	3.1	3.0	3.1	3.1	3.2	3.2	3.1	0.08
10	4.5	4.3	4.3	4.2	4.5	4.4	4.5	4.5	4.4	0.12
12	6.2	5.9	6.0	6.0	6.5	6.1	6.5	6.3	6.2	0.23
14	7.0	6.8	7.0	6.9	7.4	6.9	7.2	7.0	7.0	0.20
16	7.9	7.5	8.0	7.5	8.3	7.7	8.1	7.8	7.9	0.28
18	9.0	8.8	9.0	8.7	9.1	8.7	9.0	8.7	8.9	0.17
20	9.5	9.2	9.4	9.1	9.6	9.0	9.6	9.1	9.3	0.24
22	10.8	10.5	10.8	10.6	10.9	10.4	11.0	10.5	10.7	0.22
24	11.2	11.0	11.1	11.2	11.4	11.0	11.5	11.0	11.2	0.19
26	12.0	11.8	11.8	11.9	12.2	11.6	12.2	11.7	11.9	0.22
28	12.7	12.5	12.8	12.6	13.0	12.4	12.8	12.4	12.7	0.21

Table 9: Length of shoots of maize planted alone with leather mulch in Group D

DAY	POT 1		POT 2		POT 3		POT 4		Mean Length	Standard deviation
	Sht 1 (cm)	Sht 2 (cm)	Sht 1 (cm)	Sht 2 (cm)	Sht 1 (cm)	Sht 2 (cm)	Sht 1 (cm)	Sht 2 (cm)		
3	1.0	1.1	1.0	0.9	0.8	1.0	0.9	0.8	0.9	0.11
4	1.6	1.6	1.5	1.4	1.4	1.6	1.6	1.4	1.5	0.10
6	2.1	2.1	2.1	2.0	2.1	2.2	2.1	2.0	2.1	0.06
8	3.3	3.2	3.2	3.2	3.3	3.4	3.4	3.3	3.3	0.08
10	4.5	4.5	4.6	4.5	4.6	4.7	4.6	4.5	4.6	0.07
12	6.6	6.8	7.0	7.0	7.2	7.5	7.4	6.8	7.0	0.31
14	7.5	7.8	7.8	7.9	7.9	8.0	7.9	7.8	7.8	0.15
16	7.8	8.2	8.1	8.2	8.3	8.3	8.4	8.2	8.2	0.18
18	8.8	9.0	9.0	8.2	9.4	9.3	9.4	9.0	9.0	0.39
20	9.8	10.1	10.2	9.7	10.4	10.4	10.5	10.0	10.	0.29
22	10.4	10.5	10.6	10.4	10.9	11.0	11.1	10.4	10.7	0.30
24	11.2	11.4	11.4	11.3	11.6	11.9	12.0	11.2	11.5	0.31
26	12.6	12.8	12.7	12.7	12.9	13.0	13.3	12.7	12.8	0.23
28	14.0	14.2	14.2	14.2	14.4	14.8	15.0	14.2	14.4	0.35

4.6 Effect of Mulch Application on Maize crop planted with "Ewedu" weeds:

Maize crop planted with the introduction "ewedu" weeds in Group C was compared with maize planted with the weeds but with mulch application in Group F.

Chart 2 shows the graphical presentation comparing Group C and Group F. The chart shows an increase in length of leaves of maize in group F (with mulch) over those in group C (without mulch).

Appendices 4 and 5 show details of measurements of length of leaves for Groups C and F respectively

Appendix 4 shows that length of leaves of maize planted with "ewedu" but without mulch in Group C increased steadily up to a mean length of 27.3cm ±1.6 by day 28.

Appendix 5 shows that length of leaves of maize in Group F planted with "ewedu" and mulched also showed steady increase but much more than group C. By day 28 Group F maize showed mean length of leaves of 44.2cm± 2.15.

The increase in length of leaves of Group F over control Group C was significant ($P < 0.01$) from day 6 (Group C mean was 6.1cm ± 0.44, and Group F mean was 8.1cm ± 0.53).

Tables 10 and 11 show length of shoots for Groups C and F respectively.

Table 10 shows that length of shoots of maize planted with "ewedu" but without mulch in Group C increased steadily up to a mean length of 9.0cm ±0.18 by day 28.

Table 11 shows that length of shoots of maize in Group F planted with "ewedu" and mulched also showed steady increase but much more than group C. By day 28 Group F maize showed mean length of shoots of 15.4cm ± 0.23.

The increase in length of shoots of Group F over control Group C was significant from day 4 ($P < 0.01$) with mean shoot length of 1.5cm ± 0.05 for Group C and 1.6cm ± 0.08 for Group F.

Appendix 6 shows the result of the test of significance for the length of leaves and length of shoots for both groups C and F

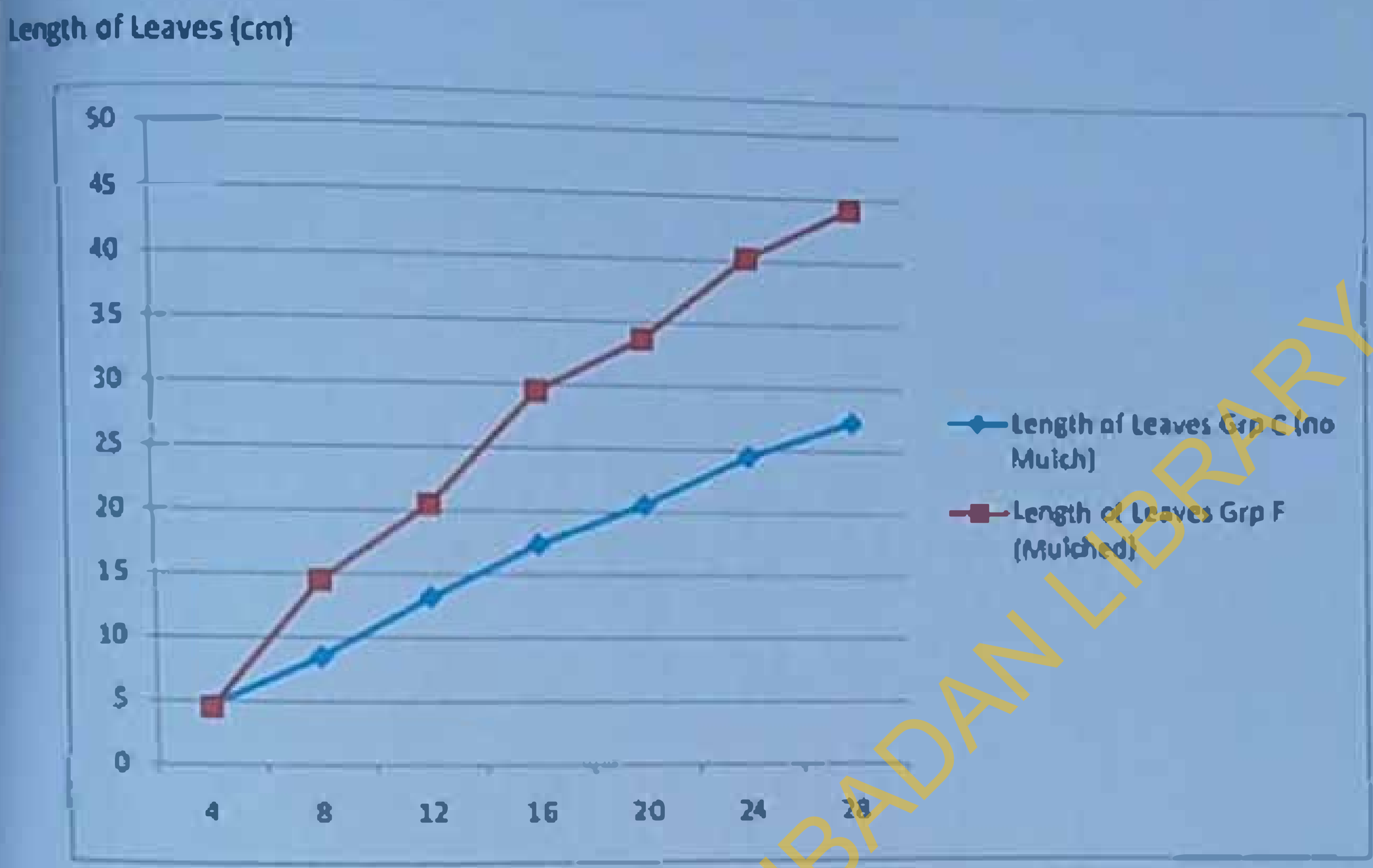

Chart 2: Graph comparing the Length of Leaves of Maize planted with "ewedu" weeds (with Mulch and without Mulch)

Table 10: Length of shoots of maize planted with "ewedu" (weeds) in Group C (without mulch)

	POT 1		POT 2		POT 3		POT 4		Mean	Standard
DAY	Sht 1 (cm)	Sht 2 (cm)	Sht 1 (cm)	Sht 2 (cm)	Sht 1 (cm)	Sht 2 (cm)	Sht 1 (cm)	Sht 2 (cm)	Length	deviation
3	1.0	0.8	0.9	0.8	1.0	0.9	1.0	0.9	0.9	0.08
4	1.5	1.5	1.4	1.4	1.4	1.4	1.5	1.5	1.5	0.05
6	2.0	2.1	1.9	1.9	1.8	1.9	1.9	2.0	1.9	0.09
8	2.8	2.9	2.6	2.7	2.6	2.7	2.8	2.8	2.7	0.11
10	3.5	3.5	3.4	3.5	3.3	3.5	3.6	3.6	3.5	0.01
12	5.1	5.0	4.8	4.9	4.8	5.0	5.1	5.1	5.0	0.13
14	6.0	6.0	5.8	6.0	5.9	6.0	6.1	6.2	6.0	0.12
16	6.4	6.3	6.2	6.5	6.4	6.4	6.5	6.6	6.4	0.13
18	7.0	7.0	6.8	7.1	7.1	7.0	7.1	7.2	7.0	0.12
20	7.5	7.4	7.3	7.5	7.6	7.4	7.5	7.6	7.4	0.10
22	7.8	7.8	7.6	7.8	7.9	7.8	7.9	8.0	7.8	0.12
24	8.2	8.2	8.0	8.1	8.2	8.3	8.3	8.4	8.2	0.13
26	8.4	8.5	8.3	8.4	8.4	8.6	8.5	8.7	8.5	0.13
28	8.9	9.0	8.8	8.8	9.1	9.2	9.0	9.3	9.0	0.18

Table 11: Length of shoots of maize planted with "ewedu" then covered with feather mulch in Group I

	POT 1		POT 2		POT 3		POT 4			
DAY	Sht 1 (cm)	Sht 2 (cm)	Sht 1 (cm)	Sht 2 (cm)	Sht 1 (cm)	Sht 2 (cm)	Sht 1 (cm)	Sht 2 (cm)	Mean Length	Standard deviation
3	0.9	1.0	1.0	0.9	0.8	0.8	1.1	0.9	0.9	0.10
4	1.5	1.6	1.7	1.6	1.5	1.6	1.7	1.6	1.6	0.08
6	2.4	2.5	2.6	2.5	2.3	2.4	2.7	2.4	2.5	0.13
8	3.8	4.0	4.2	4.0	3.9	4.0	4.4	4.2	4.1	0.19
10	6.6	7.0	7.4	7.2	6.8	7.2	7.5	7.3	7.1	0.31
12	8.0	8.2	8.5	8.2	8.1	8.4	8.5	8.4	8.3	0.19
14	9.1	9.3	9.4	9.3	9.1	9.4	9.4	9.4	9.3	0.13
16	9.6	9.8	9.9	9.8	9.6	9.7	10.0	9.8	9.8	0.14
18	10.4	10.6	10.7	10.6	10.4	10.5	10.9	10.7	10.6	0.17
20	10.8	11.0	11.1	11.0	10.9	10.9	11.4	11.2	11.0	0.19
22	11.5	11.7	11.7	11.6	11.5	11.5	11.8	11.7	11.6	0.12
24	12.3	12.4	12.4	12.3	12.3	12.4	12.6	12.5	12.4	0.10
26	13.9	14.0	14.1	14.0	13.9	13.9	14.2	14.0	14.0	0.11
28	15.2	15.4	15.5	15.4	15.2	15.1	15.8	15.6	15.4	0.23

4.7 Effect of "Ewedu" weeds on Maize crop without Mulch Application

Maize crop planted with the introduction "ewedu" weeds in Group C was compared with maize planted without the weeds in Group A in order to determine the effect of the weeds introduction on the growth of maize crop without mulch application.

Tables 15 and 18 show length of leaves for Groups A and C respectively while Tables 8 and 10 show length of shoots for Groups A and C respectively.

Results from these tables showed that Group A maize without "ewedu" weeds had longer length of leaves and length of shoots than Group C having "ewedu" weeds introduced.

The increase in length of leaves was significant ($P < 0.01$) from day 8 (Group C mean was 8.5cm ± 0.52, and Group A mean was 10.3cm ± 1.04). The increase in length of shoots was also significant from day 4 ($P < 0.01$) with mean shoot length of 1.54cm ± 0.05 for Group A and 1.45cm ± 0.05 for Group C.

This result shows that the weeds slowed down the rate of growth of the maize crop.

Table 12: Test of Significance: Effect of "ewedu" weeds on Maize (Group A maize without "ewedu" weeds, Group C maize with "ewedu" weeds)

Test	Group	N	Day	Mean	SD	Df	t	P-value	Remark
Length of Leaves	A	8	8	10.25cm	1.01	14	4.285	0.001	Significant at P< 0.01
	C	8	8	8.53cm	0.52				
Length of Shoots	A	8	4	1.54cm	0.052	14	3.326	0.005	Significant at P<0.01
	C	8	4	1.45cm	0.054				

4.8 Effectiveness of Mulch Application on Weed Control

The application of feather mulch to control the growth of "ewedu" weeds showed total prevention of weed growth. Plate 33 compared group B pots having "ewedu" planted alone without mulch and group E pots having "ewedu" planted alone and then with mulch application. By day 28 results showed no growth of "ewedu" observed in group E pots with mulch while there was growth of "ewedu" in group B pots without mulch.

Furthermore, for the "ewedu" weeds planted among the maize crops, plate 34 compared group C pots without mulch showing growth of "ewedu" while in group F pots with mulch there was zero growth of "ewedu" on day 28.

In every pot having "ewedu" planted either alone or among maize crops the mulch totally prevented the growth of "ewedu".

Plate 16: Six groups of Pots on day 4

Plate 17: Maize development and "Ewedu" on day 4

Plate 18: Comparing growth of Maize crops on day 6

Plate 19: Effect of Mulch application on growth of Maize crop (day 10)

Plate 20: Comparing growth of "Ewedu" weeds (day 10)

Plate 21. Effect of Mulch application on Maize crops (day 12)

Table 13: Length of shoots of "Ewedu "weeds planted alone in Group B

DAY	POT 1 Shoot (cm)	POT 2 Shoot (cm)	POT 3 Shoot (cm)	POT 4 Shoot (cm)	Mean shoot length (cm)	Standard deviation
6	0.4	0.4	0.3	0.4	0.38	0.05
8	0.9	0.9	0.8	0.9	0.88	0.05
10	1.5	1.4	1.4	1.5	1.45	0.06
12	2.2	2.3	2.3	2.2	2.25	0.06
14	2.8	2.8	2.8	2.9	2.83	0.05
16	3.2	3.3	3.0	3.2	3.18	0.13
18	4.0	4.1	3.9	4.1	4.03	0.10
20	4.5	4.6	4.5	4.5	4.53	0.05
22	5.1	5.2	5.0	5.0	5.08	0.10
24	5.8	5.8	5.7	5.8	5.78	0.05
26	6.3	6.4	6.4	6.5	6.40	0.08
28	6.8	6.8	6.7	6.8	6.78	0.05

Table 14: Length of shoots of "Ewedu" planted among maize in Group C

DAY	POT 1 Shoot (cm)	POT 2 Shoot (cm)	POT 3 Shoot (cm)	POT 4 Shoot (cm)	Mean shoot length (cm)	Standard deviation
6	0.4	0.4	0.3	0.4	0.38	0.05
8	0.6	0.6	0.5	0.7	0.6	0.08
10	1.1	1.1	1.0	1.1	1.1	0.05
12	1.6	1.6	1.5	1.7	1.6	0.08
14	2.1	2.2	2.0	2.2	2.13	0.10
16	2.7	2.7	2.8	2.9	2.78	0.10
18	3.2	3.3	3.1	3.3	3.23	0.10
20	3.8	4.0	3.8	3.9	3.88	0.09
22	4.3	4.4	4.3	4.4	4.35	0.06
24	4.8	4.9	4.9	5.0	4.9	0.08
26	5.2	5.2	5.2	5.4	5.25	0.10
28	5.7	5.8	5.7	6.0	5.8	0.14

Plate 22: Comparing Maize crops in four groups
on day 14

Plate 23: Comparing Maize crops in four groups on day 28

Plate 24: Assessing the effectiveness of the mulch on weed control (day 6)

Plate 25. Mulch application showing total Weed control on day 14

GROUP E
("Ewedu" planted alone with Mulch)

GROUP B
("Ewedu" planted alone without Mulch)

Plate 26: Effect of Mulch application on total Weed control on day 14

Plate 27: Mulch application showing total Weed control on day 28

Plate 28: Mulch application showing effective Weed control on day 28

CHAPTER FIVE

DISCUSSION

5.1 Generation of Waste Feathers

Results showed that the mean weight of a broiler chicken was 1.805kg while for a layer, it was 1.79kg and for a breeder it was 3.26kg. The mean weight of the breeder chicken was far higher than the other two stocks as a result of their prolonged period of feeding and longer life-span. Breeders are kept and fed for longer periods than the other stocks. They are meant to produce quality viable eggs for production of offspring. Hence the need for them to be kept in good and healthy condition. The mean weight of layers was found to be slightly lower than that of broilers as a result of the table eggs they 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.

It was difficult to get an exact percentage of feathers from each broiler bird due to the low density of the feather (0.89g/cm^3). Feathers are light and fluffy and hence become difficult to weigh. Furthermore, the feathers are usually plucked wet with water and therefore difficult to obtain the dry weight. An estimation of the percentage of waste feathers per bird as shown in table 10 indicates a mean value of 8.519% was obtained as the percentage by mass of feathers per broiler bird. This is about 166g of feathers per broiler. Most of the birds were found to be quite similar in terms of size, except some that weighed heavier than 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 4,980kg per day at 0.166Kg (166g) per bird for 30,000 birds. This quantity was generated from two poultry farms in one local government area of Ibadan.

5.2 Chemical Composition of Poultry Feathers

The chicken feathers were found to contain levels of nutrients useful 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 was as a result of 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 (Uponi and Adeoye, 2000). These nutrient contents are high enough to supply nitrogen nutrition to the test crop.

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. Using the soil nutrient rating shown in Table 6, the phosphorus and potassium contents of feathers were found to be high enough for soil amendment.

After processing the waste feathers into mulching films some of the nutrient contents, particularly the high nitrogen, phosphorus and potassium, will be available for plant growth in the soil and will easily be released into the soil within months as the feathers gradually degrade. The film would therefore be serving dual purposes of weed control and soil enrichment.

5.3 Effectiveness of Feather Mulching Film

The effectiveness of the waste feather mulching film in weed control was assessed by using seeds of maize as the sample crop and seeds of *Corchorus olitorius* as the weeds. The maize showed increased growth in the pots with the mulching film which prevented the weed growth, more than the pots without mulching film. Growth parameters measured were length of leaves and length of shoots. Measurements were taken over a period of twenty eight days.

Specifically, the maize crops planted alone and with mulch application showed a significant increase in length of leaves ($p < 0.05$) on day 20. The mean length was 27.8cm ± 2.2, for group with mulch application against a mean of 25.6cm ± 1.6 for group without mulch application. This was an increase of about 8.6%. This shows that the mulch application provided additional nutrient for soil enrichment which helped in the growth of maize leaves.

Maize crops planted with "ewedu" and then with mulch application also showed an increase in length of leaves. The increase in length of leaves was significant ($p < 0.01$) from day 6 (Group C mean was 6.1cm ± 0.44 without mulch, and Group F mean was 8.1cm ± 0.53 with mulch). This increase was about 62% over maize crop without mulch application. This large increase was possibly due to the mulch providing additional nutrient for soil enrichment. Also, the "ewedu" competed for soil nutrients with the maize as they were both growing together.

There was an increase of 13.6% ($p< 0.01$) in length of leaves of maize containing "ewedu" seeds over the maize planted alone without "ewedu" seeds (Groups F and D respectively). Since both groups had mulch application, this increase in length of leaves was possibly due to the release of extra nutrients into the soil from the decomposed "ewedu" seeds that were mulched.

A 17.91% reduction in the growth of length of shoots of "ewedu" observed from "ewedu" planted alone and those planted among maize was due to soil nutrient competition. There was zero growth of "ewedu" (total weed control) in all pots containing mulch application. This shows 100% reduction in weed growth by the feather mulch.

This project made use of plastic pots having diameter of 14cm, hence the surface of the soil needed to be covered with mulching film made of 14cm diameter per pot. Twelve pots were covered with mulching film made from the waste feathers. The mulching film made for twelve pots required about 96g 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 (8g of waste feather per pot). This comes to about 4g 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. 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.

Following successful weed control, there is no need to remove the mulching film from the soil because it will continue to gradually degrade into the soil releasing the nitrogen and other nutrient content of feather keratin into the soil. These nutrients will add to soil enrichment for subsequent planting. This makes the mulching film useful for three purposes of weed control, soil enrichment and waste feather management.

5.4 Public Health Significance

The large quantities of waste feathers generated daily could have ended up at open dumpsites where they could have negative health and economic implications among which are:

1. Environmental degradation by the solid waste feathers
2. Air pollution arising from odour of decaying wet feathers mixed with blood
3. Vector proliferation due to availability of large organic waste for the vectors
4. Increased contamination of underground water due to percolation of leachate into the ground
5. Increased possibilities of blocking of drainages by the solid waste feathers
6. Increased possibility of flooding due to blocking of drainages and
7. Economic loss arising from unnecessary expenditures on waste collection and transportation.

All these will result in poor health conditions of residents around the dumpsites through vector-borne diseases, water borne diseases and air-borne diseases. This will also lead to more economic loss in cost of treatments and loss of man/labour hours due to ill-health.

On the other hand, the use of processed waste feathers for weed control and crop enhancement has great public health value of preventing the health hazards listed above and at the same time helping towards achieving the Millennium Development Goals (MDGs) of reducing hunger and increasing food production, improving maternal and child health and achieving environmental sustainability.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.1 CONCLUSION

From the results of this project, the findings have shown that management of waste feathers should no longer be a burden to poultry industries. As a matter of fact, feathers should no longer be considered as "waste" but resource material which could be used for soil nutrient enrichment. The objective of this project which includes the assessment of the amount of waste feather generated has revealed that poultry industries do generate about 5 tones of re-usable waste feathers. Results from this study have also shown that there 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 the control of weed growth and thereby enhancing crop development.

Since the economic values of poultry feathers have been made established, consequently waste feather generation can be monitored and better managed.

6.2 RECOMMENDATIONS

Various other projects have revealed that proper waste management can result into wealth creation from wastes. This study has also shown that poultry waste feathers can be employed for the conversion of "Waste to Wealth". The use of waste feathers to generate wealth can be sustained for the following reasons:

1. There is a large quantity of waste feathers being generated daily.
2. The availability of cheap source of organic nitrogen in the waste feathers
3. There is a sustainable means of converting the resource content of the waste feathers into mulching film.
4. The efficiency of the film in weed control and enhancement of crop development has been shown.
5. There is the need to increase crop production and to improve food security in the country in meeting the millennium development goals.

It is hoped that future work can further explore the use of cheaper sources of plasticizer than glycerol in order to drastically reduce cost of producing the mulching film and to make its production more profitable. Finally, there is need for field validation of the results obtained in this work.

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APPENDICES

APPENDIX 1: Table of Length of leaves of maize planted alone in Group A

	POT 1		POT 2		POT 3		POT 4		Mean Length	Standard deviation
DAY	Lf 1 (cm)	Lf 2 (cm)	Lf 1 (cm)	Lf 2 (cm)	Lf 1 (cm)	Lf 2 (cm)	Lf 1 (cm)	Lf 2 (cm)		
4	5.5	3.6	5.6	3.4	5.5	3.3	5.4	3.6	4.5	1.08
6	7.5	4.8	7.2	4.4	7.8	4.5	7.3	4.4	6.0	1.58
8	11.0	9.0	10.9	9.0	11.2	9.1	11.0	10.8	10.3	1.01
10	14.0	13.0	14.3	12.8	14.0	12.9	14.0	13.1	13.5	0.62
12	16.2	14.4	16.0	14.5	15.8	14.3	16.3	14.3	15.2	0.92
14	19.0	16.5	19.1	16.3	18.8	16.0	19.3	16.1	17.6	1.62
16	22.0	17.8	22.2	17.5	22.0	17.2	23.0	17.2	19.9	2.63
18	25.4	22.0	26.0	21.7	25.8	21.8	26.1	21.7	23.8	2.16
20	26.8	24.3	27.4	24.0	27.1	24.0	27.2	24.0	25.6	1.64
22	28.6	25.5	29.0	25.0	28.6	25.2	28.9	25.2	27	1.91
24	32.0	28.6	32.1	28.2	32.3	28.4	32.6	28.2	30.3	2.01
26	33.2	32.0	33.5	31.6	33.8	31.5	34.0	31.7	32.7	1.06
28	36.4	34.6	36.8	35.0	37.0	34.7	37.8	35.2	35.9	1.21

APPENDIX 2: Length of leaves of maize planted alone with feather mulch in Group D

	POT 1		POT 2		POT 3		POT 4		Mean Length	Standard deviation
DAY	Lf 1 (cm)	Lf 2 (cm)	Lf 1 (cm)	Lf 2 (cm)	Lf 1 (cm)	Lf 2 (cm)	Lf 1 (cm)	Lf 2 (cm)		
4	5.5	3.5	5.5	3.4	5.6	3.6	5.6	3.8	4.6	1.06
6	7.5	5.6	7..2	5.5	7.6	5.8	7.8	5.8	6.5	1.06
8	12.2	9.3	12.0	9.3	12.0	9.6	12.3	10.9	11.0	1.36
10	16.0	12.5	16.1	12.8	15.9	12.8	16.0	12.2	14.3	1.84
12	18.4	15.0	18.5	15.4	18.3	14.9	18.8	14.4	16.7	1.93
14	20.3	17.6	20.4	18.0	19.9	17.7	20.5	17.5	19.0	1.4
16	23.4	19.2	23.4	19.4	23.0	19.8	23.6	19.0	21.4	2.15
18	25.5	22.0	25.8	22.2	25.4	22.5	26.1	21.9	23.9	1.9
20	29.7	25.6	29.6	25.8	29.8	26.0	30.0	25.6	27.8	2.2
22	33.0	28.2	32.8	28.5	33.0	28.8	33.4	29.0	30.8	2.4
24	36.3	31.6	36.0	32.2	36.1	33.0	35.9	32.7	34.2	2.0
26	38.8	33.2	38.2	35.0	38.4	36.5	38.3	35.8	36.8	2.0
28	40.5	35.8	41.0	36.4	40.2	38.4	41.0	37.5	38.9	2.1

APPENDIX 3: Test of Significance: 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
	D	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
	D	8	20	27.763cm	2.158				

APPENDIX 4: Length of leaves of maize planted with "ewedu" (weeds) in Group C (without mulch)

	POT 1		POT 2		POT 3		POT 4		Mean Length	Standard deviation
DAY	Lf 1 (cm)	Lf 2 (cm)	Lf 1 (cm)	Lf 2 (cm)	Lf 1 (cm)	Lf 2 (cm)	Lf 1 (cm)	Lf 2 (cm)		
4	5.5	3.5	5.5	3.6	5.5	3..5	5.4	3.6	4.7	1.02
6	6.5	5.5	6.4	5.8	6.5	5.6	6.4	5.7	6.1	0.44
8	9.0	8.0	8.9	8.1	9.0	7.9	9.1	8.2	8.5	0.52
10	13.0	11.2	12.9	11.0	13.4	10.8	13.2	11.0	12.1	1.15
12	14.5	12.0	14.0	12.3	14.4	12.0	14.1	12.4	13.2	1.13
14	16.5	14.6	16.2	15.0	16.3	14.8	16.0	14.9	15.5	0.78
16	18.2	16.4	18.0	16.9	18.3	16.6	17.9	16.8	17.4	0.79
18	19.1	18.0	19.2	18.2	19.6	18.3	19.0	18.4	18.7	0.57
20	21.5	19.4	21.8	19.5	22.0	19.5	21.2	19.7	20.6	1.15
22	23.2	20.8	23.4	21.0	23.8	21.2	23.0	21.4	22.2	1.24
24	26.0	22.3	26.4	22.7	27.0	22.6	26.1	22.9	24.5	2.0
26	27.1	23.5	27.8	23.9	28.2	23.8	27.4	24.0	25.7	2.07
28	28.8	25.7	28.6	26.0	29.4	25.8	28.2	25.8	27.3	1.6

APPENDIX 5: Length of leaves of maize planted with "ewedu" then covered with feather mulch in Group F

	POT 1		POT 2		POT 3		POT 4		Mean	Standard
DAY	Lf 1 (cm)	Lf 2 (cm)	Lf 1 (cm)	Lf 2 (cm)	Lf 1 (cm)	Lf 2 (cm)	Lf 1 (cm)	Lf 2 (cm)	Length	deviation
4	5.6	3.5	5.5	3.5	5.5	3.4	5.5	3.6	4.5	1.08
6	8.5	7.6	8.6	7.5	8.5	7.4	8.6	7.8	8.1	0.53
8	15.2	14.0	15.0	13.8	15.1	13.6	15.4	14.0	14.5	0.73
10	19.0	17.6	18.8	17.2	18.9	17.2	19.4	17.8	18.2	0.88
12	21.4	20.0	21.1	19.3	21.0	19.2	21.8	20.0	20.5	0.98
14	27.6	24.4	27.0	24.2	28.0	24.3	28.4	25.1	26.1	1.80
16	30.2	28.4	29.7	28.0	30.8	28.6	31.0	29.0	29.5	1.13
18	32.3	31.0	32.0	30.8	33.5	31.2	33.9	31.7	32.1	1.14
20	34.4	32.7	34.2	32.3	35.0	32.2	35.8	32.7	33.7	1.37
22	38.2	35.5	37.8	35.5	38.8	33.8	39.0	34.0	36.6	2.13
24	42.0	38.5	41.6	38.8	42.3	37.2	42.9	38.2	40.2	2.23
26	43.2	40.0	43.1	40.4	44.0	39.8	44.9	40.0	42.0	2.08
28	45.5	42.2	45.2	42.8	46.6	41.9	47.0	42.0	44.2	2.15

APPENDIX 6: Test of Significance: Effect of Mulch on Maize planted with "ewedu" seeds (Group C without Mulch, Group F with Mulch)

Test	Group	N	Day	Mean	SD	DF	t	P-value	Remark
Length of Leaves	C	8	6	6.05cm	0.438	14	-8.242	0.000	Significant at P<0.01
	F	8	6	8.06cm	0.534				
Length of Shoots	C	8	4	1.45cm	0.05	14	-4.638	0.000	Significant at P<0.01
	F	8	4	1.61cm	0.08				