A DISSERTATION ON

Development of Eco leather and its Utilization in Secondary Food Packaging : A Sustainable Approach

SUBMITTED TO THE
DEPARTMENT OF BIOENGINEERING
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IN PARTIAL FULFILMENT
FOR THE
DEGREE OF MASTER OF TECHNOLOGY
IN FOOD TECHNOLOGY

BY
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UNDER THE SUPERVISION OF

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DECLARATION FORM

I, **Soumya Dwivedi**, a student of **M.Tech Food Technology** (II Year/ IV Semester), Integral University have completed my six months dissertation work entitled **“Development of Eco Leather and Its Utilization in Secondary Food Packaging : A Sustainable Approach”** successfully from **Department of Bioengineering, Integral University** under the able guidance of **Dr. Rahul Singh, Assistant Professor, Integral University, Lucknow.**

I, hereby, affirm that the work has been done by me in all aspects. I have sincerely prepared this project report and the results reported in this study are genuine and authentic.

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Certificate that Ms. **Soumya Dwivedi** (2100101772) has carried out the research work presented in this thesis entitled **"Development of Eco Leather and Its Utilization in Secondary Food Packaging : A Sustainable Approach"** for the award of **M.Tech Food Technology** from Integral University, Lucknow under my supervision. The thesis embodies results of original work and studies carried out by the student herself and the contents of the thesis do not form the basis for the award of any other degree to the candidate or to anybody else from this or any other University/Institution. The dissertation was a compulsory part of her **M.Tech Food Technology** degree.

I wish her good luck and bright future.

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TO WHOM IT MAY CONCERN

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I wish her good luck and bright future.

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Place: Lucknow   Soumya Dwivedi

Dated:

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ACRONYMS

SN.NO.	ACRONYM	FULLFORMS
1.	BOD	Biological oxygen demand
2.	COD	Chemical oxygen demand
3.	FWP	Floral waste powder
4.	SA	Sodium Alginate
5.	EMC	Equilibrium moisture content

ABSTRACT

Eco – leather (also known as faux leather , artificial leather , vegan leather , pleather) is a kind of environment friendly leather . In the production process of eco – leather ,the use of chemical products is lowered and limited for all the tanning and disposal process. Eco – leather is a man made material that mimics the look and feel of real leather .It is made from natural resources such as cork, fruit peels , plant leaves and other renewable materials .It is a sustainable alternative to traditional leather that does not use animal products or harsh chemicals in its production process. Usually cow leather , an animal product , is a common material which is used for making leather products. Despite being robust , it raises moral , social , and environmental concerns. Another biomaterial manufactured without fleshing any animal is environmental friendly and animal free leather , often known as vegan leather or eco –leather or artificial leather .As an alternative to cow leather or any other type of animal leather , is the creation of vegan leather using agricultural waste which includes waste flowers and shedded leaves can be investigated .further this vegan leather can be used as a secondary packaging material in food packaging industry . Secondary packaging designates the packaging used to group various pre packed products together. Secondary packaging does not come in direct contact with the actual product . It plays a vital role in branding and marketing the product it serves to group several products together for ease of handling , transport and storage. It must also be durable enough to protect the primary packaging during transport and storage. In this present project work , "**Development of Eco Leather and Its Utilization in Food Packaging : A Sustainable Approach** " eco – leather or vegan leather was made using the agricultural waste such as flower waste collected from various sites such as temples , flower shops and shedded leaves .and then this leather is examined for its use as a secondary packaging material. Various analysis was done such as ,biodegradability , effect of acid , effect of alkali , effect of salt , moisture content , folding endurance .

Keywords : Eco leather , secondary packaging , biodegradability

CHAPTER 1
INTRODUCTION

Environment friendly and animal free leather also known as " vegan leather " or " artificial leather " , is an alternative biomaterial produced without the use of any animal component. This bio based material compared to traditional leather shows similar physic – chemical and mechanical properties. Moreover, recent studies show that this class of materials are gradually gaining market in the fashion industry as leather substitutes. In the present study, efforts towards the preparation of such bio based materials using novel formulations agro – waste components is accomplished. This material may be considered as a prospective leather alternative for application in leather accessories, such as hand bags and upper shoe sole(**nabanita saha et.al. 2020**).

Vegan alternatives are being actively sought to replace animal leather with bio-based alternatives such as plant fibers or fungal mycelium fibers in the face of global climate change]. Several different vegan leather alternatives to real leather are available on the market today, including Muskin®, Desserto®, Appleskin®, Vegea®, SnapPap®, Kombucha,Teak Leaf®, Pinatex®, and Noani® (**cornelia wjunow et.al.2023**) Vegan alternatives to leather were sought , as many wanted to stop using animal leather together Being vegan or wearing vegan products and clothing has become something of a fashion trend (**selina sultanova et.al.2023).**

Flowers are considered as holy things and hence are presented by pilgrims to their idols. Every day these flowers offered in temples are left unexploited and consequently become solid-waste. This flower waste dump and gets collected at religious sites like Temples, Mosques and Gurudwaras (**Mishra, 2013**). In India, West Bengal stands 4th to promote flowers after Andhra Pradesh, Karnataka and Tamil Nādu. Indian is a city with many temples, being visited by a large number of devotees. India is a country with diverse religions where, worshiping or praying is the means of living and people offer several offerings to the deities, out of which floral aids are found in enormous quantity. Consequently, temple waste has an extraordinary share of flower waste in the total waste. After satisfying their purpose, flowers laterally with other waste, discovery their way into the garbage or are cast-off into river, sea or oceans, which instigating many environmental problems**.(** **Qiyang Wang et.al 2013**) In the list of offered flowers in temples are marigold, rose, jasmine, chrysanthemum, hyacinth, hibiscus, etc. This floral waste can be suitably accomplished and utilized in various value-added form.

Waste dumping is a principal concern in the world. Inoffensive disposal of floral waste has been a cause of concern for the temple management. Deterioration of environmental quality, climate change and management of disposed waste are the chief topics to human society**(MS Waghmode et.al 2018).** One of the chief reasons of environmental contamination is mis-management of organic waste including temple waste. The floral waste is straight inclined into the rivers, oceans, etc. which has awful influence on the water quality as well the living organisms existing in the water bodies and its vicinity. Flower or floral waste come from hotels, wedding gardens, worship places and a spread of civilizing and sacred ceremonies , which make them a usual source of waste **(S Dutta et.al 2021).**

India in terms of flower promotion. Banaras (UP), one of India's holiest cities, lacks enough coverage for the disposal of large amount of flower problems associated with improper floral waste disposal Incineration, which manages the combustion of waste substances to a non-flammable residue or ash and exhaust gases, is one of the most used disposal and remediation strategies for floral waste. In the United States and Europe ,incineration is the method of choice for a variety of hazardous and poisonous waste streamsris. Flowers that have dried and rotted are discarded as garbage in landfills and water bodies. Sri Lanka and India are two instances of countries where around 40% of total flower production is unsold and wasted on a daily basis . This flower debris is thrown into bodies of water or dumped on undeveloped ground, polluting both the environment and the water **(AL Srivastava et.al 2021).**

The flower waste gives the streets and highways a filthy appearance, as well as distorting the image of ghats along various water bodies. However, a modern methodology exists to convert floral wastes into value-added products such as compost, biofuels, bioethanol, organic acids, pigments, dyes, polyhydroxybutyrate-co-hydroxyvalerate production, food products, bio surfactants production, sugar syrup, incense sticks, handmade paper production, and so on **(P Singh et.al 2017).**

The Ganges is believed by Hindus to be the most sacred of all rivers but nowadays it is extremely polluted due to disposal of various kinds of toxic chemicals and waste into the rivers. Among the muck were tonnes of flowers – marigolds , roses , jasmine , hibiscus , hyacinth and chrysanthemums – discarded by temples and worshippers. These flowers are used in Hindu rituals and are considered sacred , meaning they can't be disposed of along with other waste. But depositing them in a river is sometimes part of the ritual and as a result flowers are dumped in water bodies daily where they leach out harmful chemicals from pesticides , and eventually decay into mulch that contaminates the water. This floral waste can be utilized for making leather , which can be further used in secondary food packaging **(K D Yadav et.al 2022)**

Advances in food packaging play a primary role in keeping the U.S. food supply among the safest in the world. Simply stated, packaging maintains the benefits of food processing after the process is complete, enabling foods to travel safely for long distances from their point of origin and still be wholesome at the time of consumption . The principal roles of food packaging are to protect food products from outside influences and damage, to contain the food,and to provide consumers with ingredient and nutritional information (**Coles 2003**). Traceability, convenience, and tamper indication are secondary functions of increasing importance. The goal of food packaging is to contain food in a cost-effective way that satisfies industry requirements and consumer desires, maintains food safety, and minimizes environmental impact.

The study has following objectives :

1. To develop biodegradable eco leather using floral waste(agro waste).
2. To study the physic – chemical and biodegradability of eco – leather.
3. To utilize eco- leather as secondary food packaging.

CHAPTER 2
REVIEW OF LITERATURE

In this chapter , a review of the work related to the topic **" Development of Eco Leather and its Utilization in secondary food packaging : A Sustainable Approach"** has been discussed in detail. The topic of research was made in order to know the present status of research in the area . The knowledge of these studies would help the researchers to proceed in an appropriate direction in the present study and draw meaningful conclusions. .

2.1 Leather

Leather is a strong , flexible and durable material obtained from the tanning , or chemical , of animal skins and hides to prevent decay . The most common leathers come from cattle , sheep , goats , buffalo , pigs , and hogs and aquatic animals such as seals and alligators . Leather is a natural fabric made using tanned animal skin . It is believed to be the first fabric crafted with human hands. The first conclusive use of leather appears to have been by the Egyptians around 1300 BC . Yet it wasn't just the Egyptians that had discovered the technique of creating leather , as use of the material has been found in primitive colonies across Asia , Europe and North America around the same time . At this time leather was used in a simple manner to create clothing , especially foot wraps to protect the body and keep warm. By 1200 BC the Greeks had already started using their leather more decoratively for clothing and armour **(AD Covington et.al 2020).**

Leather industry has an important role in generating revenue , particularly in india . The leather purification process consumes enormous quantity of water leading to generation of wastewater effluents reaching to 150 tons per day . leather industry wastewater is characterized to have increased COD , BOD , reduced form of chromium , NaCl , calcium , magnesium , sulphide compounds , and other hazardous contaminants including oils , tannins and biocides , posing detrimental effects on environment and humans . Leather is also no friend of the environment , as it shares responsibility for all the environmental destruction caused by the meat industry as well as the pollution caused by the toxins used in tanning (**S Harris 2014**). Leather manufacturing involves the use of hazardous chemicals, which pose significant health and safety risks to workers. Exposure to these chemicals can cause skin and respiratory problems, and long – term exposure can lead to cancer. Leather industry is one of the most polluting industries . The leather processing is responsible for unfavourable impact on environment. Solid waste produced in leather industry include animal skin trims, animal hairs, flesh wastes, buffing dust and keratin wastes. All of these wastes contain protein as its main component. If this protein is not utilized properly, it will responsible for dangerous pollution problems to environment(**P Maina et.al.2019).**

Leather manufacturing has significant environmental impacts and sustainability challenges. Some of the main environmental concerns associated with leather production include the use of hazardous chemicals, high water usage, air and water pollution, and deforestation. Leather has one of the greatest impacts on eutrophication of all materials used for fashion, a serious ecological problem in which runoff waste creates an overgrowth of plant life in water systems, which suffocates animals by depleting oxygen levels in the water and is the leading cause of hypoxic zones, also known as "dead zones". The production methods of vegan or eco-leather are way more eco-friendly and cost-effective than that of synthetic leather where hazardous chemicals are used. The plant based leather is softer, durable and displays good tensile strength, stability and temperature resistance **(K Joseph , N Nithya 2009).** Vegan leather donot contribute to pollution because it does not need any kind of chemical during its processing . Tanning process is used for converting animal's skin to leather, here during processing of vegan leather tanning is not done. Vegan leather is the greatest option to replace synthetic leather as it does not involve animals.

Fig.2.1. Animal leather

2.2 The rise of Vegan Leather / Eco Leather

Eco leather is any leather alternative that does not come from animal . Most eco – leather is made from plant – based material . The word ‘leather’ according to the Oxford dictionary is the material made by tanning or otherwise dressing hides. Hides are the skins of animals. Anything made from synthetics or natural cork cannot be called leather. “Vegan Leather ” is a term created by marketing experts to convince vegans they are getting a product as good as the real thing **.**

Vegan leather , also known faux leather , or a leather alternative – is a leather like fabric that isn’t made from the skin of animals . Instead , vegan leather is made from a variety of plastic and plant materials. (**Disha Goyal et.al. 2011).** Eco leather , also know as plant based leather or vegan leather , is a type of material made from plant based sources as an alternative to traditional leather , which is typically made from animal hides . Plant based leather can be made from a variety of sources such as pineapple leaves , mushrooms , apple leaves , cactus leaves and recycled plastic . some additional plant based leathers include coffee leather , grape leather , and olive leather .Vegan leather or Eco friendly leather are referred to as plant based leathers , they are environment friendly. One of the primary benefits of using vegan leather instead of traditional animal-based leather is that it is environmentally friendly (**NT Minh et.al.2021).** Animal agriculture is considered one of the leading causes of global warming, and producing traditional leather involves chemical processes such as tanning and dyeing. In contrast, plant-based vegan leatherette can be manufactured using more sustainable methods that do not produce harmful emissions .

VEGAN LEATHER	**ANIMAL LEATHER**
1.Free from animal source	1.Made from animal skins.
2.Cost effective	2.Expensive as compared to vegan leather
3.no use of chemicals	3.use chemical
4. breathable	4. unbreathable

5. uniform finishing	5. visual imperfections
6. can be cleaned easily	6. needs specialized cleaning care
7. structurally damaged with too much manipulation	7.stretches and shrinks naturally

Table 2.1. Difference between vegan leather and animal leather

2.3 Types of Eco leather

There are various types of eco leather or vegan leather made from different types of plant based material available in the market such as apple leather , cactus leather , cork leather , mushroom leather , pineapple leather etc.

2.3.1 Apple Leather

It is also known as Apple Skin , is a plant – based leather invented by Alberto Volcan from Bolzano , Italy .The first products made with apple leather were manufactured in 2019 , and is most commonly used for small accessories like wallets. One of the leading production companies in Apple leather is OLIVER CO , based in Bermondsey , South London . Here the apple waste was turn into leather by two processes , firstly apple waste is turned into puree , which is then spread flat on a sheet and dehydrated , next the sheet is combined with polyurethane to add durability .In the second process apple waste is turned into a powder , which is then combined with polyurethane and coaterd onto a cotton and polyester backing. AppleSkin apple leather is PETA approved Vegan , USDA approved . Despite the name , apple leather is not entirely biodegradable . After being combined with polyurethane , the leather is only 50 % plant based. However apple leather production emits less carbon dioxide (CO_2) than PU leather **(C Valenzuela et.al. 2015).**

2.3.2 Cactus leather

It is a plant based leather produced from the mature leaves of the nopal (prickly – pear) cactus native to Mexico. Founded by entrepreneurs Adrian Lopez Velarde and Marte Cazarez , Desserto was the first company to manufacture cactus leather .

The process of cultivating cactus leather has several steps . First , the mature pads of the cactus are harvested , cleaned , and ground down . Next , the pads are dried under the sun for three to five days . Next , fibres are separated from the dried pads and then mixed with chemicals to form a bioresin , which is then poured over a carrier such as cotton or polyster . Desserto cactus leather is mostly biodegradable , consisting of 92% organic carbon content . Most steps in the cactus leather production process are also sustainable in practice **(S Williams 2022).**

2.3.3 Cork Leather

It is a plant based leather made from bark harvested from cork oak trees native to many parts of Europe . Mahi Leather in Kanpur , Northern India , and HZcork located in Dongguan , China which produces both cork leather and cork fabrics . The process for harvesting and manufacturing cork leather is much simpler than apple and cactus leather. The process of turning bark into leather does not involve toxic chemicals nor does it emit pollution , cork trees also do not release harmful chemicals when burned **(V Geraldes et.al. 2009)**

The downside to the use of cork leather are that it is not as durable as animal leather , and despite being one of the most environmentally friendly plant based leathers , it is underutilized by fashion companies due to its unique texture.

2.3.4 Mushroom Leather

It is a plant based leather made from mycelium , the vegetative filaments that make up the branches of fungi . Mushroom leather was first developed in 2013 by Philip Ross and Jonas Edvard and called MYX , which was made from the waste of the oyster mushroom industry . Mushroom leather is primarily produced in Indonesia .This leather has one of the most complicated production processes of the plant – based leathers.

In most cases , mushroom leathers are completely biodegradable , however , similar to cork leathers , when extra durability is needed , the mushroom leather is reinforced with polyurethane , which decreases its biodegradability(**J Bustillos et.al. 2020).**

2.3.5 Pineapple Leather

It is a plant based leather made from the cellulose fibres of pineapple leaves. The pineapple leather , Pinatex , was developed by Carmen Hijosa and is produced by textile company Ananas Anam.

To create pineapple leather , the fibres are extracted from the leaves and felted together to produce a non –woven mat , the mat is then washed , pressed , and dyed , this is considered the raw Pinafelt . The felt is then combined with non – biodegradable polyurethane resin for durability. Despite the Pinafelt consisting of 100 % plant –based materials , the combination with polyurethane in the final stage means that Pinatex will not naturally biodegrade **(P Sharma et.al. 2016).**

2.4 Floral Waste

Floral waste refers to dried and decayed flowers and thus , dumped in landfills , various water bodies , etc. Floral waste is one of the biggest pollutants , on land and water , accounting for nearly a third of all solid waste in the country , according to statistics. Because they have been offered in prayers , the dead flowers are considered holy , and not to be disposed of with the other rubbish**(MB Kulkarni et.al. 2019).**

Every year 80,00,000 metric tonnes of waste flowers are dumped into the river Ganga. Floral waste , reportedly , accounts for 16 % of the total river pollutant .While rotting flowers affect the water quality , the pesticides used on them leach into the waters and harm marine life . Floral waste is a huge part of agro waste, when not properly disposed of this waste can end up in landfills or water bodies, where it can cause environmental problems. In india many places of worship generate 20 tonnes of flower waste daily. Floral waste constitutes a major part of agricultural waste in India. Agricultural waste includes plant residues, weeds, leaf litter, sawdust, forest waste, flower waste and livestock waste. As flower waste contains enough nutrients and lignocellulosic material, it can be used for various purposes such as bioenergy and biofuel production, compost preparation, lawn conditioner, eco-friendly fragrance sticks, soaps, rose water and other food products, etc. **(Vinod kumar et .al. 2020).** The composition of flower waste produced varies from place to place like in Darghas the flower waste mostly consists of jasmine flowers, in Gurudwaras mainly marigold flowers are used and in case of temples marigold, lotus, rose etc**. (Elango and Govindasamy, 2018).** Flower waste is composed of highly lignocelluloses, cellulose, crude proteins, crude fibres, essential oils, nitrogen bearing compounds, etc. Different types of flower have different properties in them which make them useful for different purposes.

2.5 Floral Waste Management

Waste management is one of the biggest challenges that the world faces everyday. It is well known that the municipal solid waste includes household waste , commercial and market area waste , slaughter house waste , institutional waste , horticulture waste , waste from road sweeping , silt from drainage , and treated biomedical waste **(Isher Ahluwalia and Utakarsh Patel ,2018)**. India is a country with diverse religions where , worshiping or praying is means of living and people offer several offerings to the deities, out of which floral aids are found in large quantity. Temple waste has an extraordinary share of flower waste in the total waste. Inoffensive disposal of floral waste has been a cause of concern for the temple management . One of the major reasons of environmental contamination is mis – management of organic waste including temple waste . The floral waste is directly inclined into the rivers , oceans , etc. which has major influence on the water quality as well as the living organisms present in water bodies . flower or floral waste comes from hotels , wedding gardens , worship places and a spread of civilizing and sacred ceremonies , which make them a usual source of waste (**kunal adhikary 2021**).

The management of floral wastes by conversion into different value-added products viz., compost; biofuels; biogas; bioethanol; organic acids; pigments; dyes; polyhydroxybutyrate-co-hydroxyvalerate production; food products; biosurfactants production; sugar syrup. The waste also have other applications viz., making of incense sticks; handmade paper production; etc. The value added products obtained from floral wastes viz; compost can be used for various plant growth; biogas for electricity generation; food products as nutrients and additives. The dyes and pigments from floral wastes will have applications in various textile industries; while biofuels and bioethanol can solve the problem of energy crisis. The waste can thus be converted into wealth. The floral wastes can have important application in biosorption which will help in the treatment of waste waters and other industrial effluents **(D Sharma et.al. 2021)** Flower waste management from temples can serve as a sustainable source of raw material for handmade paper production . This method not only reduces the generally discarded waste produced by city temples, but also recycles and reuses it as an environment friendly paper.

There are some standard disposal and treatment options, land filling; incineration which is controlled combustion of waste materials to a non-combustible residue or ash and exhaust gases. In USA and Europe, incineration is preferred for many organic hazardous and toxic waste streams. In land treatment final state of the waste is disposed by making intimate contact with the soil. The land treatment exploits the natural capacity of the soil to return substances to a condition forthcoming the unique state from which they were won by a process of extraction and purification**(U Racha et.al. 2022).**

Volatilization method is also used for the treatment and disposal of wastes. It is effective for the removal of volatile compounds from soil by using commercial units that heat up the soil to between 100 and 500 A _C. Dried and decayed flowers are considered waste material and thus, dumped in landfills, various water bodies, etc. The example is of a country like Srilanka and India, where about 40% of the total production of flowers are unsold and wasted daily . These flowers are thrown into water or dumped into landside causing water pollution as well as environmental pollution . Many of us avoid throwing flowers and other items which are used for prayers in the garbage and instead put them in the plastic bags and throw them directly in the water bodies. Such disposal of waste creates problems like eel and worm development, water and land pollution and foul odor. Solid waste and littering can degrade the physical appearance of water bodies and cause deterioration of water quality **(P Tiwari 2018).** The floral waste generated gives a filthy look to the streets and roads and also distorts the image of ghats along the rivers. However, now there is a modern approach to convert the floral wastes into value-added products viz., compost; biofuels; bioethanol; organic acids; pigments dyes; polyhydroxybutyrate-co-hydroxyvalerate production; food products; biosurfactants production; sugar syrup; incense sticks; handmade paper production; etc.

Management and handling of flower waste become difficult as compared to the kitchen and other municipal waste because religious sentiments of people are attached with the flowers that are offered to god which afterward becomes part of temple waste (**Samadhiya et al.,2017**).

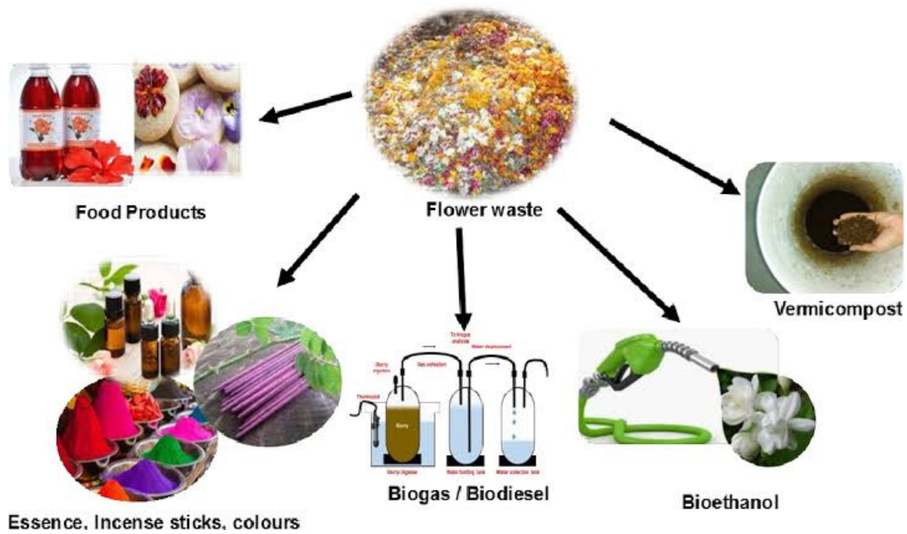


Fig.2.2. Other utilization of floral waste

2.6 Food Packaging

The principal roles of food packaging are to protect food products from outside influences and damage, to contain the food, and to provide consumers with ingredient and nutritional information(**Coles 2003**). Traceability, convenience, and tamper indication are secondary functions of increasing importance. The goal of food packaging is to contain food in a cost-effective way that satisfies industry requirements and consumer desires, maintains food safety, and minimizes environmental impact. Food packaging can retard product deterioration, retain the beneficial effects of processing, extend shelf-life, and maintain or increase the quality and safety of food. In doing so, packaging provides protection from 3 major classes of external influences: chemical, biological, and physical. Packaging maintains the benefits of food processing after the process is complete, enabling foods to travel safely for long distances from their point of origin and still be wholesome at the time of consumption. However, packaging technology must balance food protection with other issues, including energy and material costs, heightened social and environmental consciousness, and strict regulations on pollutants and disposal of municipal solid waste. Any assessment of food packaging's impact on the environment must consider the positive benefits of reduced food waste throughout the supply chain. Package design and construction play a significant role in determining the shelf life of a food product. The right selection of packaging materials and technologies maintains product quality and freshness during distribution and storage. Materials that have traditionally been used in food packaging include glass, metals (aluminium, foils and laminates, tinplate, and tin-free steel), paper and paperboards, and plastics(**K Marsh and B Bugusu 2007).**

In achieving the sale of the product, the packaging must also protect the product, not only from transit and physical damage, but also from microbial and bacterial deterioration as well as climatic hazards, like heat, cold, moisture, frost etc. In this role, especially with respect to food product, packaging significantly reduces the wastage of food during the transit journey. Packaging must also identify, track and trace the product. Consumers are now more than ever aware of product shelf lives, product traceability to the packer / product originator, enabling effective product recall in instances where product integrity is questionable. Packaging must also differentiate itself on the shelf where it competes with thousands of other packaging for consumer choice(**G L Robertson 2005).**

Packaging is basically characterized into primary , secondary and tertiary packaging .

2.6.1 Primary Packaging

Primary packaging is also known as sales packaging . Primary packaging is the term used to designate the layer of packaging in immediate contact with the product; in other words, it is the first packaging layer in which the product is contained. As such, primary packaging is constructed both with the product itself and any existing secondary layers of packaging in mind. The properties of the product (form, dimensions and consistency) evidently dictate the main priorities of primary packaging. Primary packaging can have diverse applications and functions, depending on the product, and transit and storage variables. The most obvious, and important, function is to protect and preserve the product from damage, external interference or contamination, spoiling and chemical imbalances (**AN Tanksale et.al. 2021**). Primary packaging also serves to keep a product in storage, often for long periods of time. In this case, it is imperative that primary packaging keep the product absolutely sealed off from its environment. Ease of handling and shelving is a further aspect of primary packaging to be considered, so as to ensure the product can be easily handled by consumers. The examples of primary packaging are as limitless as the range of available consumer products. Some of the most common types include blister packs, clamshell packaging, shrink-wrapping, paperboard packaging, unit dose packs and many more .

2.6.2 Secondary Packaging

Secondary packaging is also known as grouped packaging. Secondary packaging designates the packaging used to group various pre-packaged products together (the first layer of packaging, in direct contact with the product, is called primary packaging).As secondary packaging is not in direct contact with the actual product, its use and application usually differ distinctly from those of primary packaging, although the purpose of both types may at times converge. Secondary packaging can be said to have two central functions:

 Branding & Display. Secondary packaging plays a vital role in the marketing strategy surrounding the product. This is especially relevant in the case of display packaging.

 Logistics. Secondary packaging serves to group several products together for ease of handling, transport and storage. This means that secondary packaging must be able to:

- Contain relatively large volumes of primary packaged products.

- Transport the product safely to its retail or consumer destination.

- Keep the primary packaging in its original condition during storage.

Secondary packaging is intended to protect not only the product, but also the primary packaging, which often is the packaging most visible to the consumer in retail displays. The most common examples of secondary packaging include cardboard cartons, cardboard boxes and cardboard/plastic crates(**L Meherishi et.al. 2021).**

The U.S. Food and Drug Administration (FDA) regulates packaging materials under section 409 of the federal Food, Drug, and Cosmetic Act. The primary method of regulation is through the food contact notification process that requires that manufacturers notify FDA 120 d prior to marketing a food contact substance (FCS) for a new use. An

FCS is “any substance intended for use as a component of materials used in manufacturing, packing, packaging, transporting or holding of food if the use is not intended to have a technical effect in such food” (21 USC §348(h) . The use of paper and paperboards for food packaging dates back to the 17th century with accelerated usage in the later part of the 19th century (**Kirwan 2003**). Paper and paperboard are sheet materials made from an interlaced network of cellulose fibers derived from wood by using sulfate and sulfite. The fibers are then pulped and/or bleached and treated with chemicals such as slimicides and strengthening agents to produce the paper product. FDA regulates the additives used in paper and paperboard food packaging (21 CFR Part 176). Paper and paperboards are commonly used in corrugated boxes, milk cartons, folding cartons, bags and sacks, and wrapping paper. Tissue paper, paper plates, and cups are other examples of paper and paperboard products.

2.6.3 Tertiary packaging

Transport packaging focuses on the packaging requirements of goods in transit, in particular for items traveling overland by road or rail (as opposed to overseas packaging). Transport packaging is very often a local affair (see export packaging for international transport) and therefore needs to be designed with local conditions and expectations in mind(**SH Chung et.al.2018)**. Tertiary packaging is used to protect manufactured goods for shipping or storing. Tertiary packaging facilitates the protection handling and transportation of a series of sales unit or secondary packaging.

2.7 Sodium Alginate

Sodium Alginate is the sodium salt form of alginic acid and gum mainly extracted from the cell walls of brown algae .Its chemical formula is $NaC_6H_7O_6$ .It is a neutral salt in which the carboxyl groups of alginate are bonded with a sodium ion. Sodium alginate is a linear polysaccharide derivative of alginic acid comprised of 1,4-beta –d – mannuronic and (M) and alpha-I-guluronic (G) acids. **(Hay et.al .2010**). Sodium alginate is a cell wall component of marine brown algae , and contains approximately 30 to 60 % alginic acid .

Sodium Alginate is slowly soluble in cold water , forming viscous , colloidal solution. It is insoluble in alcohol and hydroalcoholic solutions in which alcohol content is greater than 30 % by weight.(**shilpa .A. et.al .2003).** Due to distribution of chain lengths , alginate solutions are not clearly Newtonian and behave as pseudoplastic fluid . When dissolved in pure water , their reduced viscosity is expected to increase very rapidly with dilution (**Fuoss and Strauss 1948). A**lginaters have been reported to undergo proton catalyzed hydrolysis , which is dependent on time , pH , and temperature .Ability of alginate to form two types of gel depend on pH , i.e. an acid gel and an ionotropic gel , gives the polymer unique properties compared to neutral macromolecules**(Tonnesen et.al . 2002**).

Numerous studies have tested the high level of safety of sodium alginate in foods. Allergy tests conducted with sodium alginate have shown that the material is not allergic . Sodium alginate has not been shown to possess any eye or skin irritation properties .The ingestion of sodium alginate had no significant effect on haematological indices , plasma biochemistry parameters , urinalysis parameters , blood glucose and plasma insulin concentrations , breath hydrogen concentrations .(**D M Anderson et.al. 1991**) **A**lginates have been widely used as table disintegrant , binding agent , viscosity modifying agent , as a stabilizer in disperse system in the production of suspension and emulsion and also as thickening agent in pharmaceutical industries .(**Nikhil k. Sachan 2009)**

In the food industry , alginate has been used to coat fruits and vegetables , as a microbial and viral protection product , and as a gelling , thickening , stabilizing or emulsifying agent .(**Roxana G. Puscaselu et.al. 2020**) Alginate is an effective product used in the food industry as well as in the management of metabolic disorders such as obesity and diabeties.

CHAPTER 3

MATERIALS AND METHODS

Current study deals with the utilization of agricultural waste like floral waste and shredded leaves to make leather using sodium alginate , glycerine , distilled water . Primarily floral waste including marigold , rose , lily , chrysanthemums etc was collected from various locations such as temples , flower shops . Floral waste is the basic raw material used in the making of this eco leather . This raw material was collected from different temple sites , and then it was dried using hot air oven or sun drying for 24 hours , then it was grinded using grinder . further this raw material was mixed with distilled water , sodium alginate , glycerine . 7 samples having different composition of the raw material and other materials was made and then further testings on all the 7 samples were done.

Experiments were conducted to verify and validate the optimal results by comparing the experimental values with predicted values . This chapter provides the details of material and methodology used during the entire study of the investigation . All the experiments were performed in the Central instrumentation facility (CIF) Laboratory of department of Bioengineering , Integral University , Lucknow (India) .Detail of the raw material collection and procurement , various instruments and equipment's used for the experimentation , selection of independent and dependent variables , experimental design analysis has been discussed in this chapter.

3.1 Experimental Materials

3.1.1 Collection of raw materials

Flower waste was collected from different temple sites of Lucknow and Kanpur . This floral waste was then washed under running water and then it was dried under sunlight for 24 hours or in hot air dryer. Then the dried floral waste was grinded in grinder to make it in powder form . Then the sieving id done for constant particle size 150µm . The floral waste powder was kept in air tight container for further processing . Most of the floral waste which was collected from different temple sites included marigold and rose flowers. Marigold was approximately 85 % among the waste collected and rose and other flowers and small leaves constitute the other 15 %.Approximately 5 kg of waste was collected from all the sources .The waste collected was not more than 3 days old . Then it was washed properly with water and all the unwanted materials present in the floral waste were removed after washing it was dried properly till the flowers become that much dried so that they can be easily grinded into powder form . After grinding into powdered form it was properly stored in air tight container so that moisture do not incorporate into it till further use. Floral waste collected from different temple sites is shown in the figure below.

Fig.3.1. Floral waste

3.1.2 Chemical Glassware's and Equipment

All the chemicals used during the experimentation were AR grade and purchased from the standard suppliers. The borosil grade glassware were used during the study . All Glasswares were cleaned , washed thoroughly with water and rinsed with distilled water and dried before use . Various equipment used during the study are in given table 3.1

Equipment / Instruments	Specifications/ Make	Purpose
Electronic balance	MSW , 10A/VA Delhi Mettler AE 166 , Capacity 100g , LC : 0.0001 g	Weighing the sample
Grinder	Usha rapid mix 500- Watt copper motor mixer 500 Watt	Size reduction
Hot air oven	IFTD . 6.MS. Size 150 mmL *900mm *600mm	Even Drying
Distillation unit	GLSI-SCU-25AQ	Distilled water
Muffle furnace	GMP model Model no. KI-179	Ash estimation
Refrigerator	Model RS62K6227SL Samsung 220V-50Hz	Extract storage
Vernier callipers		Measuring thickness
Tensile tester		Tensile strength , elongation at break

Table 3.1. List of equipment's / instruments

3.2 Preliminary Experiments

Preliminary experiments were planned to adopt the suitable technique , its parameters and their level and other factors for the final experiments. Different procedure was used in this study for the development of leather using minimum possible chemicals. This procedure conducted in the experiment were compared to the results of traditional approaches as mentioned in the review literature in the results and discussion section.

S.No.	Parameter	Value
1.	Solvent	Distilled water
2.	Particle size	150 , 300 (µm)
3.	Drying time	24 , 48 , 72 (hrs)
4.	Composition	1:1, 1:2, 2:1, 1:1.5 (FWP : SA)

Table 3.2 . Various parameters considered for preliminary experiments

3.3 Flowchart of Experiment

Collect agricultural waste including floral waste

⇩

Now wash the collected floral waste

⇩

Dry the floral waste under sun for 24 hours or in hot air dryer for 3 -4 hours

⇩

Grind the dried waste using grinder

⇩

Mix the floral waste powder with sodium alginate , glycerine and distilled water

⇩

After mixing properly store the mixture at a cool place for 24 hours

⇩

Now pour the mixture on the frame

⇩

Dry it for 2 to 3 days

⇩

Eco leather is finally prepared

⇩

Now give shape accordingly

3.4. Experimental Procedure

The **prese**nt research deals with the development of eco-leather , a substitute of animal leather using agricultural waste such as floral waste and for their application in the secondary food packaging . The entire study was carried out in three phases .

In the first phase the floral waste was collected from different temple sites and then it was washed and dirt present in it was removed and then it was dried under sun for 24 hours . followed by grinding it into powder form . In the second phase this powdered form of floral waste is mixed with sodium alginate and glycerine and after mixing thoroughly it was kept in cool place for 24 hours . In the third phase this mixture was poured on to a frame and dried for 2 – 3 days .After it completely gets dried it is cut into desired pieces and given required shape.

3.5. Preparation of eco leather

5 g powder sample of floral waste powder and 2.5 g sample of sodium alginate was used . Distilled water (100ml) , glycerol (5 ml) were mixed and the mixture was cooled by keeping in the cool place for 24 hours . The mixture was agitated until it becomes smooth mixture without any air bubbles present in it **(J Shi et.al. 2021).** Now this mixture is poured in a mould or on a smooth surface and then it is dried for about 2 – 3 days under normal temperature and environment and for about 1 day in tray dryer at 40 degree celcius.

7 samples of eco leather were made . Each sample was having different compositions of agro waste and sodium alginate .Sample 1 was having composition of agro waste and sodium alginate in the ratio of 1:1, sample 2 was having composition in the ratio of 2:1, sample 3 was having composition in the ratio of 1:2. All other composition ratios are shown in the table below.

SN. No.	Sample	Agro waste (gm)	Sodium Alginate (gm)
1.	Sample 1	5	5
2.	Sample 2	5	2.5
3.	Sample 3	2.5	5
4.	Sample 4	2.5	2.5
5.	Sample 5	2	1
6.	Sample 6	1	2
7.	Sample 7	0.5	0.5

Table. 3.3. Composition ratio of agro waste and sodium alginate

Fig.3.2. Mixture poured on the petridish for drying

3.6. Biodegradability Tests

3.6.1. Biodegradation by Composting

Biodegradable composting method was employed to test the biodegradability of the prepared leather **(khan A. et.al. 2006**). 2g of prepared sample was vacuum dried for 24 hours at 45°C and buried in to the municipal solid waste mixture (for 15 days) for possible biodegradation . The content was kept in an oven at 55 ° C , at which the maximum growth of thermophiles microorganisms was occurred . The buried bioplastic sample was weight after 3 days for a period of 15 days in order to determine the percentage of weight loss .

3.6.2. Bench – Scale Simulated Composting

In this test , the compost was consisted of 50 % (w/w) cow manure and garden soil . Bioplastic samples each of 2g were used for this analysis and the samples were buried in a separate vessel container consisting of inoculums (cow manure and garden soil) . For characterization , the bioplastic samples were removed from the compost daily in order to calculate the weight loss . The temperature of the compost was measured and recorded daily . Percentage weight loss for the materials were measured according to Khan . et al . 2006 , by the following equation :

$$\% \ Weight\ loss = \frac{W1-W2}{W1} x100 \qquad (1)$$

Where ,

W1 and W2 were the samples weight before and after treatment **.**

3.7. Chemical Tests

3.7.1. Effect of Acids

2g of the prepared sample was weight and , then put into Sulphuric acid with concentration of 50 % . The dried samples were weight periodically for 6 days .The percentage weight loss was observed after each time period **(C Liu et.al. 2022).** All the 7 samples of bio-leather were dipped into the acid solution containing container for a period of 6 – 7 days as shown in the figure below.

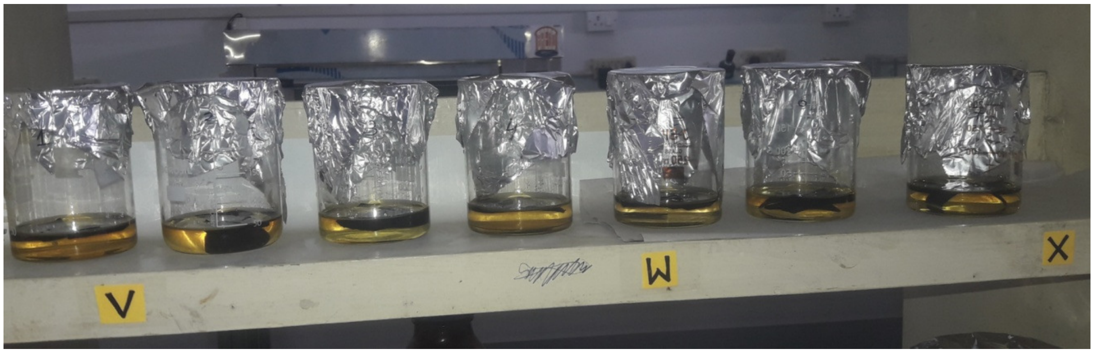


Fig.3.3. Samples of bio-leather dipped into acid.

3.7.2. Effect of Alkalis

2g of the prepared sample was put into alkali solution (sodium hydroxide) with concentration (50%) .The percentage weight loss was calculated daily for a period of ten days (**RB Choudhary et.al. 2004).** All the 7 samples of bio-leather were dipped into the alkali solution containing container for a period of 9-10 days as shown in the figure below.

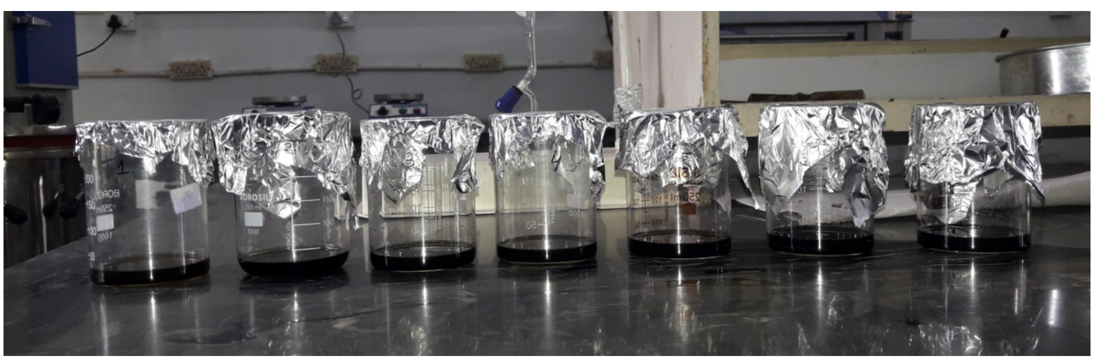


Fig.3.4. Samples of bio-leather dipped into alkali solution**.**

3.7.3. Effect of Salts

2g of the prepared sample were mixed with different solid salts in different container, and left for 5 days, with periodic weighing every day, and its resistance to the action of salts (The sodium chloride , trisodium orthophosphate and lead acetate)was observed **.** In my experiment I have used sodium chloride salt (**RB Choudhary et.al. 2004**). 50% concentration of sodium chloride solution was made and bio leather samples wee dipped into them for a period of day Samples dipped into salt solution are shown in the figure **.**

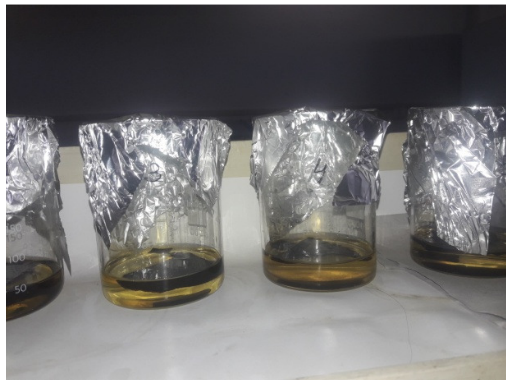


Fig.3.5.samples dipped into salt solution

3.8 . Moisture Content

Equilibrium moisture content (EMC) is very important to determine the desirable conditions of microorganisms growth , which causes material deterioration and degradation . Moisture content is simply how much water is in a product . It influences the physical properties of a substance , including weight , density , viscosity , conductivity , and others **(SS Nielsen 2010).** It is generally determined by weight loss upon drying.

For measuring the moisture content of leather samples :

1. First take the petridishes according to the sample and weight the petridishes .
2. Now take 2 g of each sample in the petridish .
3. Calculate the combined weight of sample and petridish before drying.
4. Now place the sample into an oven for 2 minutes at 105 ° C .
5. The final weight was obtained by weighing the plastic using an electronic balance until constant weight was gained .
6. The test was repeated consequently .

Formula for calculating moisture content :

$$MC\ (\%) = (mf - mi) / mf \times 100\ \% \quad \text{(ii)}$$

MC = moisture content

mf = final weight (constant weight after drying in oven)

mi = initial weight (weight before drying in oven)

Fig.3.6. Samples kept in oven for moisture content measurment

3.9. Folding Endurance

Folding endurance is to check the durability of the plastic . It is the number of double folds required to make a test piece break under standardized conditions. The leather was taken and was folded equally until it breaks .Then it was unfolded and the number of folding was counted (**D Zhang et.al. 2023**). In paper testing , folding endurance is defined as the logarithm (to the base of ten) of the number of double folds that are required to make a test piece break under standardized conditions :

$$\mathbf{F = \log10d\ ,} \quad \text{(iii)}$$

Where F is the folding endurance and d is the number of double folds.

3.10. Tensile strength

Tensile strength is defined as a stress , which is measured as force per unit area . It is the maximum loadd that a material can support without fracture when being stretched , divided by the original cross –sectional area of the material . Tensile strength refers to the tensile force on the unit cross section of the broken part of the sample when the sample of the finished leather is pulled to break at a certain rate , expressed in MPa **(M Meyer et.al. 2021)**. The purpose of measuring the tensile strength of leather is to understand the deformation of the leather under the action of external force and the maximum tensile force that the leather can withstand , so as to test the durability of the upper surface.

A tensile tester machine was used for measuring the tensile strength of the leather samples . instruments it includes were Die knife , fixed weight thickness tester , vernier calliper , tensile testing machine . Die knife is used to cut the sample . the knife edge must be sharp to get a clear and neat sample. The measuring range of the tensile tester machine must be suitsable for the measured object . The moving speed of the movable gripper of the tensile machine must be uniform , which should be (100 ± 20) mm/min . The clamping surface of the gripper should have a serated surface to ensure that the sample does not move during the stretching process . The minimum length of the clamping surface of the clamp in the direction of the force is 45mm , and the specimen is fixed mechanically or pneumatically **(R Yadav et.al. 2022).**

Now cut the specimens from the sample in a specific shape with a die knife . For measuring the tensile strength of the sample first we will calculate the crossectional area of the sample .

Cross-sectional area of the sample = the width of the sample x the thickness of the sample

Now determine tensile strength , first adjust weight of tensile strength and then adjust the moving speed of the movable clamp of the tensile machine to (100 ± 20) mm/min. Then correct the pointer on the reading plate of the tensile tester to “0” . Now clamp the specimen in the upper and lower clamps . Now start the machine until the sample breaks , and record the maximum force value at the break .

The tensile strength σ (MPa) of the sample is calculated according to the following formula :

$$\sigma = F/S \qquad \textbf{(iv)}$$

where ,

σ – tensile strength , MPa

F – Maximum force value when the sample breaks ,(N)

S – the cross-sectional area of the sample break point , mm^2

Fig.3.7. Tensile Tester Machine

3.11. Elongation at break test

Elongation at break is the measure of a materials ductility and toughness . This measurement shows how much a material can be stretched , as a percentage of its original dimensions , before it breaks . It indicates the ability of a material to undergo significant deformation before failure .

Elongation at break is the percentage increase in length that a material will achieve before breaking . This is usually measured using test method ASTM D412 . Elongation at break is an important mechanical property of leather . It measures how much bending and shaping a material can withstand without breaking . It quantifies the amount of deformation a material can withstand before breaking **(D Palomba et.al. 2014).**

Elongation at break is important in assessing a material's capacity to plastically deform in a safe way , avoiding brittle failure . It is critical in applications for materials like rubber and plastic where the material will be stretched repeatedly or subjected to impacts. In some cases it is also used in leather for determining its strength and toughness.

A high tensile elongation value is typically preferred , because it denotes a high degree of ductility and flexibility**(W Brostow and D Zhang 2020).** It helps prevent failure under difficult circumstances. Elongation at fracture is also crucial in making packaging materials like protective plastic packaging . To guarantee that the products they contain are safeguard during shipping and handling , these materials must be able to stretch and flex without breaking.

Formula for Elongation at Break :

$$\text{Elongation at Break} = \frac{(\text{final length} - \text{original length})}{\text{Original Length}} \times 100$$

Steps for performing elongation at break :

1. Measure the original length of the specimen which is to be tested.
2. Now perform a tensile strength test according to a standard method .
3. Now measure the final length at the end of the test , after the test specimen has fractured .
4. Subtract the original length from the final length to obtain the change in length .
5. Divide the change in length by the original length and multiply by 100 % to obtain the total percent elongation .

CHAPTER 4

RESULTS AND DISCUSSION

In this research eco leather , a type of vegan leather was prepared using agro waste especially floral waste which was collected from different temple sites of Lucknow and Kanpur. Preliminary experiments were carried out before the final sample was made these preliminary experiments were carried out on the basis of solvent , particle size , drying time , composition. After the preliminary experiments 7 samples of eco- leather were made then all the samples were tested on several parameters.

4.1 Eco leather prepared

Eco leather was prepared by using floral waste and sodium alginate . Different samples of leather was made .All the samples made by different quantity of floral waste and sodium alginate .Due to the use of different quantities raw material all the 5 samples made were of different weight and thickness .out of all the 5 samples sample 4 was found to be perfect. Weight of the samples was taken using electronic weighing balance and thickness of the leather was measured using vernier callipers scale.

SN. No.	**Samples**	**Weight (g)**	**Thickness (mm)**
1.	Sample 1	8.21	0.18
2.	Sample 2	5.65	0.16
3.	Sample 3	4.02	0.13
4.	Sample 4	3.86	0.11
5.	Sample 5	2.73	0.08
6.	Sample 6	2.56	0.05
7.	Sample 7	1.18	0.03

Table 4.1. . weight and thickness of all the different 7 samples

Fig.4.1. Eco-leather made

4.2 Composition of different samples of eco leather

All the 5 samples made of eco leather made were made of different composition of raw materials. All the 7 samples have different ratios of the two important raw material used for making this leather i.e. floral waste powder and sodium alginate .

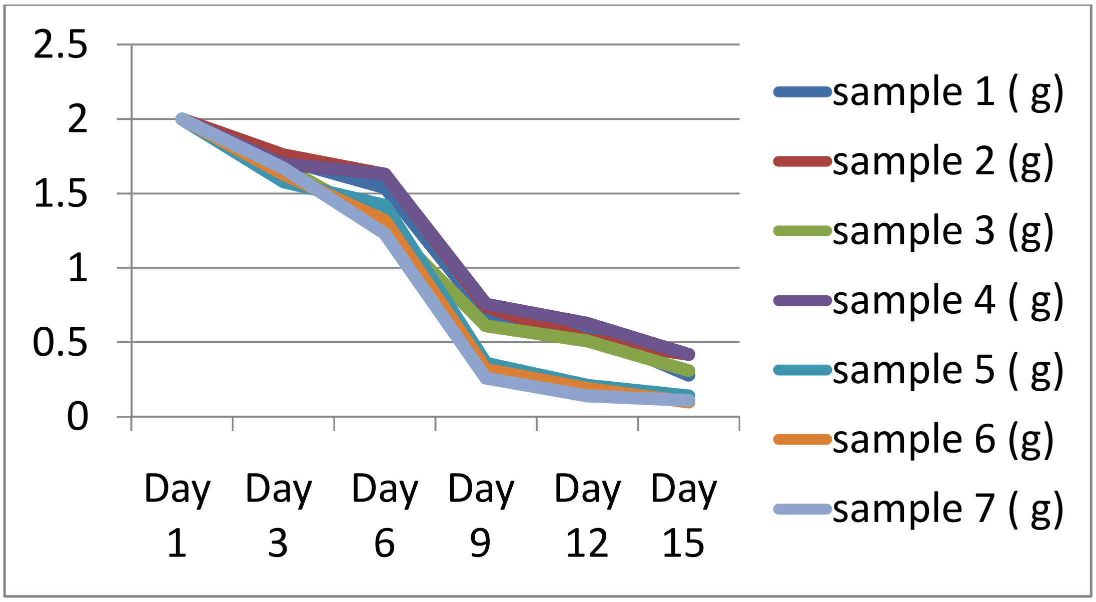
In the first sample of eco leather the ratio of floral waste powder to sodium alginate was 1:1 .In the second sample of leather the ratio of floral waste powder and sodium alginate was 2:1 . In the third sample of leather the ratio was 1:1(different weight) . In the fourth sample of leather the ratio of floral waste powder and sodium alginate was 2:1(different weight) .In the fifth sample of the leather the ratio of floral waste powder and sodium alginate was 1:1 (different weight).

4.3 Results of Biodegradability Tests

Biodegradation test was carried out on all the samples of eco- leather by using two methods : by bench-scale simulated composting and by composting.

4.3.1 Biodegradibility by Bench-scale simulated composting

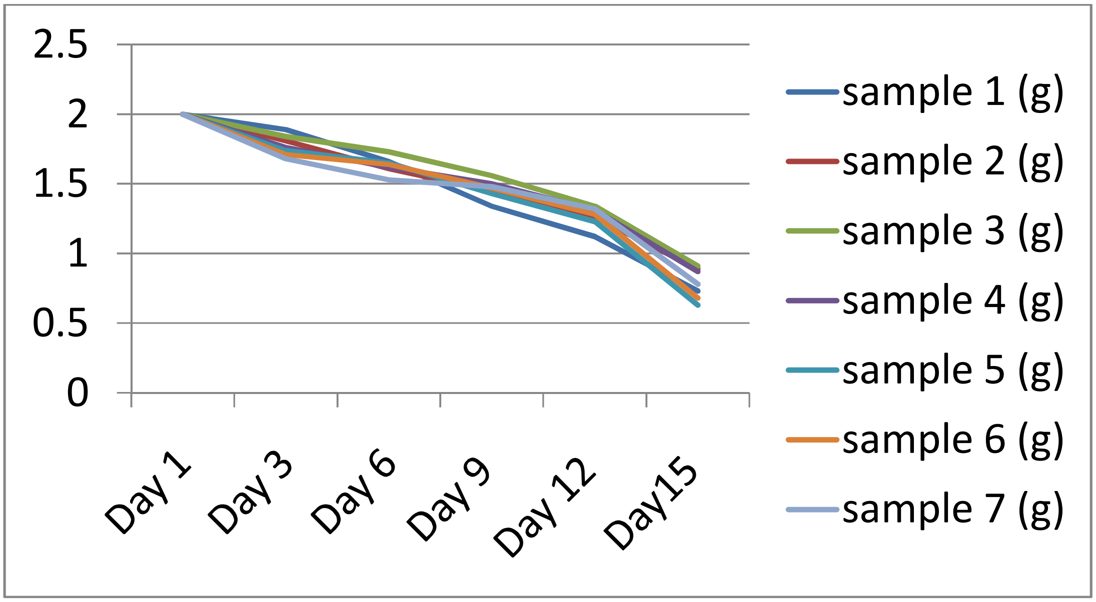
In this test , the samples of eco-leather were buried into the compost for a period of approximately 20 days and eco-leather were removed from the compost daily in order to calculate the weight loss. After every 3 days the samples were taken out and measured .Percentage weight loss of eco-leather were measured till the time percentage loss becomes zero. In the graph shown below it is showing that weight of the leather which was buried in the compost kept on decreasing day by day and till 15 days it degraded completely because all the raw materials which are being used in making this eco leather were biodegradable and environment friendly which makes this eco leather more biodegradable as compared to other leathers present in the market.



Graph.4.1. (a) biodegradability by bench – scale simulated composting

4.3.2. Biodegradability by Composting

In this method the eco-leather samples were buried into the municipal solid waste mixture for a period of 20 days . and after every 3 days its weight was measured and percentage weight loss was calculated and it was found that sample weight loss becomes zero till 15 days. These graphs of composting shows the rate of weight loss in the eco leather. In other leathers it was found that rate of biodegradability was very slow, it may take years to degrade a small sample of animal leather . But since my leather is free from any chemical toxins it took only 15 days to degrade it completely under soil.



Graph 4.1.(b) biodegradability by composting

Fig. 4.2 Sample after biodegradation by composting after 3 days

Fig. 4.3. Sample after biodegradation by bench-scale simulated composting after 3 days

4.4 Folding Endurance Result

Folding endurance test of all the samples were done manually. Number of folds of all the samples were found to be different and it was found that the maximum number of folds was found in the sample 4 which was found to be 950 folds.

SN. No.	Samples	Number of folds
1.	Sample 1	600
2.	Sample 2	780
3.	Sample 3	917
4.	Sample 4	950
5.	Sample 5	850
6.	Sample 6	888
7.	Sample 7	500

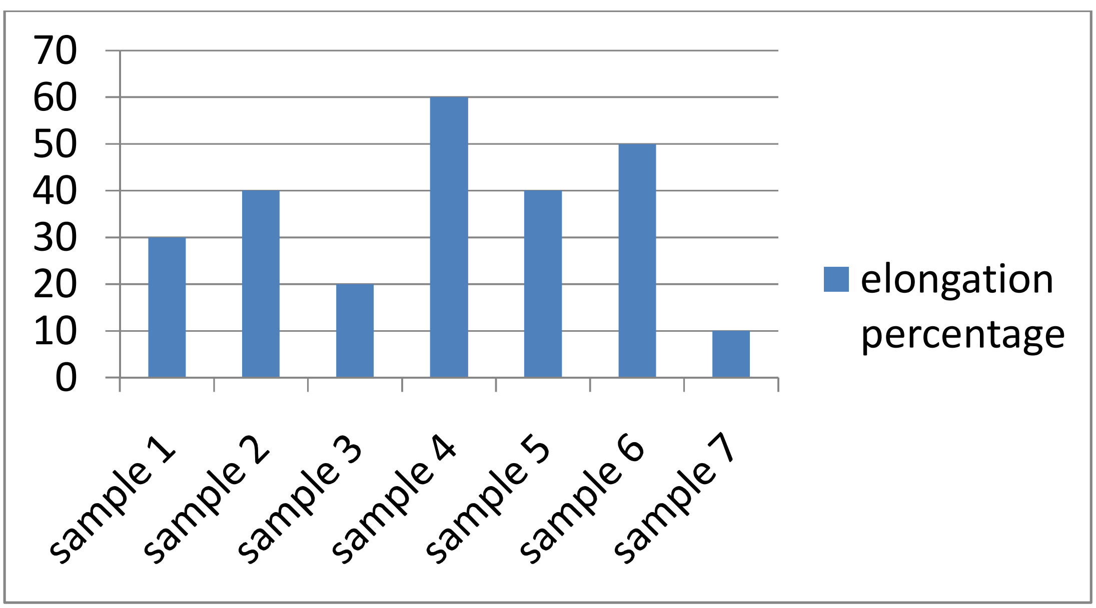
Table.4.2. folding endurance test result of all the samples

4.5 Result of Elongation at Break

Elongation at break of all the samples were measured using test method ASTM D412. Original length and final length of all the 7 samples of eco-leather were measured . Elongation at break of samples were measured using formula and it was found that elongation at break of sample 4 was found to be highest that is 60 %. Though elongation at break of animal leather is very high as on it tanning is done and various types of chemicals are used on it. Use of these chemicals and various other processing on animal skin makes it gain more strength and thus elongation of such leather is also more as compared to the eco leather made here. Since this made eco leather is to be used for several food packaging materials thus no chemicals were used on it to make it compleletely toxin free and environment friendly. But elongation at break of our sample was satisfactory as compared to apple leather, cork leather.

SN No.	Sample	Original length(cm)	Final Length(cm)	Elongation at Break (%)
1.	Sample 1	5	6.5	30
2.	Sample 2	5	7	40
3.	Sample 3	5	6	20
4.	Sample 4	5	8	60
5.	Sample 5	5	7	40
6.	Sample 6	5	7.5	50
7.	Sample 7	5	5.5	10

Table.4.3. elongation at break test results



Graph 4.2. graph of elongation at break

4.6) Tensile Strength test result

Tensile strength of the samples were measured using tensile tester machine .The purpose of measuring the tensile strength of leather is understand the deformation of the leather under the action of external force and the maximum tensile force that the leather can withstand , so as to test the durability of the upper surface. For measuring the tensile strength of the sample first cross-sectional area of the sample was calculated then using the above mentioned formula tensile strength of the samples were calculated. Among all the 7 samples tensile strength of sample 4 was found to be the highest i.e. 4.2 MPa .

SN No.	**SAMPLE**	**F(N)**	**S(mm)**	**σ(MPa)**
1	sample1	38	10	3.8
2	sample2	36	10	3.6
3	sample3	38	10	3.8
4	sample4	42	10	4.2
5	sample5	40	10	4.0
6	sample6	34	10	3.4
7	sample7	29	10	2.9

Table 4.4. tensile strength result

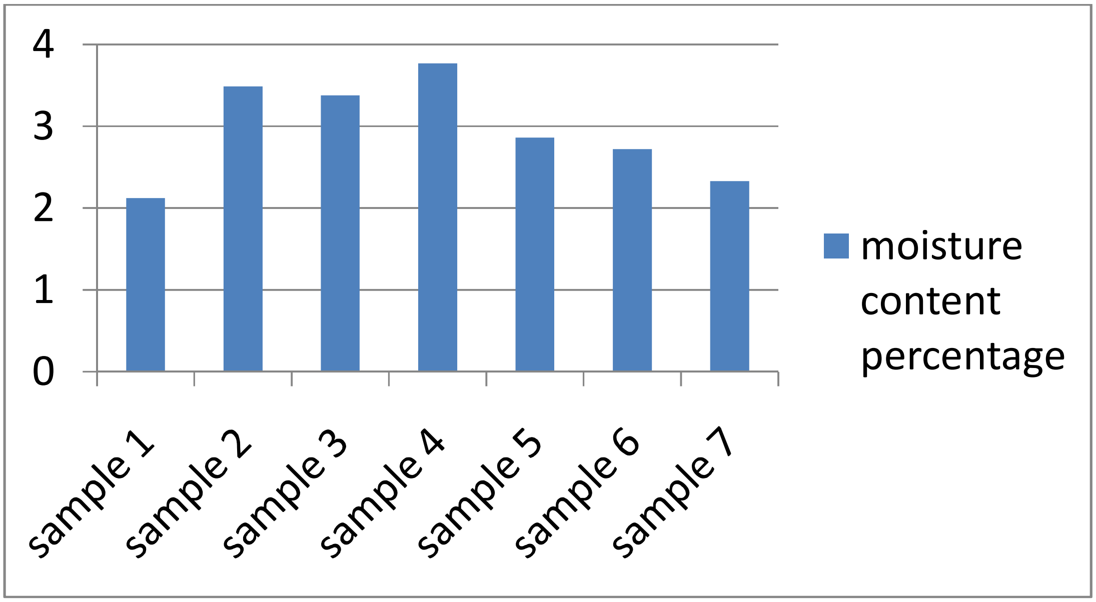
4.7 Result of Moisture Content

Moisture content of the samples was determined using hot air oven. EMC is very important to determine the desirable conditions of microorganisms growth , which causes material deterioration and degradation. It is generally determined by weight loss upon drying. After measuring the initial and final moisture content of the samples moisture content percentage was calculated using above mentioned formula.

SN No.	Sample	Wt. Of petridish (g)	Sample Weight (g)	Petri + sample (g)	Final weight (g)	Moisture Content (%)
1.	Sample 1	42.785	2.080	44.865	43.71	2.12
2.	Sample 2	45.001	2.166	47.167	46.63	3.49
3.	Sample 3	45.108	2.071	47.179	46.69	3.38
4.	Sample 4	42.286	2.236	44.504	43.94	3.77
5.	Sample 5	42.086	2.036	44.122	43.32	2.86
6.	Sample 6	41.066	2.038	43.104	42.21	2.72
7.	Sample 7	42.288	2.016	44.304	43.29	2.33

Table .4.5. for moisture content result

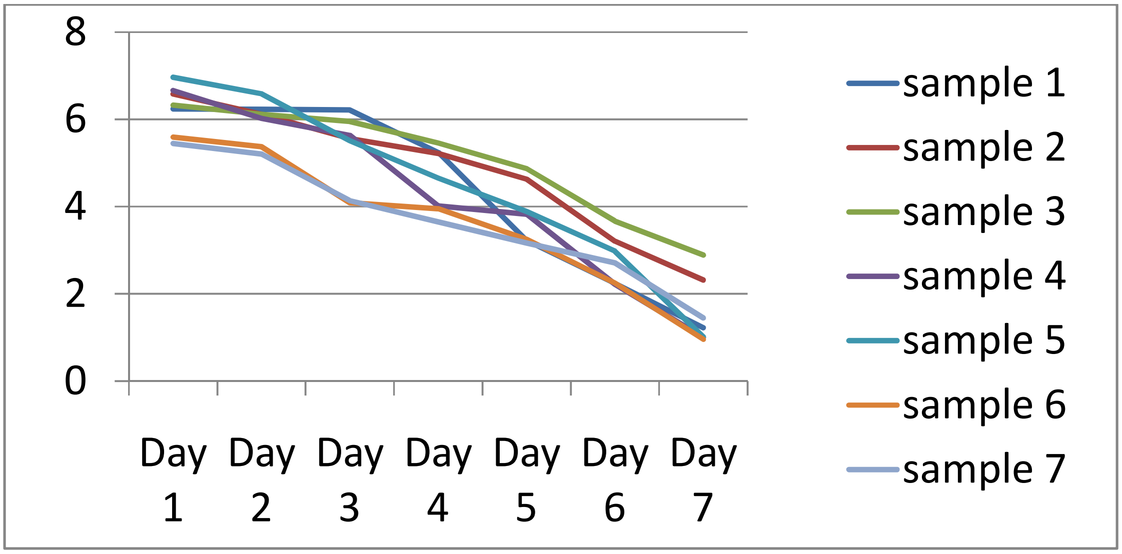
Moisture content percentage values is shown below using graph and it was found that moisture content of sample 4 was the highest i.e. 3.77% and that of sample 1 was found to be lowest i.e. 2.12 %. Sample having more moisture content cannot be broken easily and will have more flexibility whereas sample having less moisture content can be broken easily and will have less flexibility. In the graph x-axis shows the samples and y-axis shows the moisture content percentage of samples.



Graph.4.3. moisture content percentage

4.8 Result of Effect of Acid

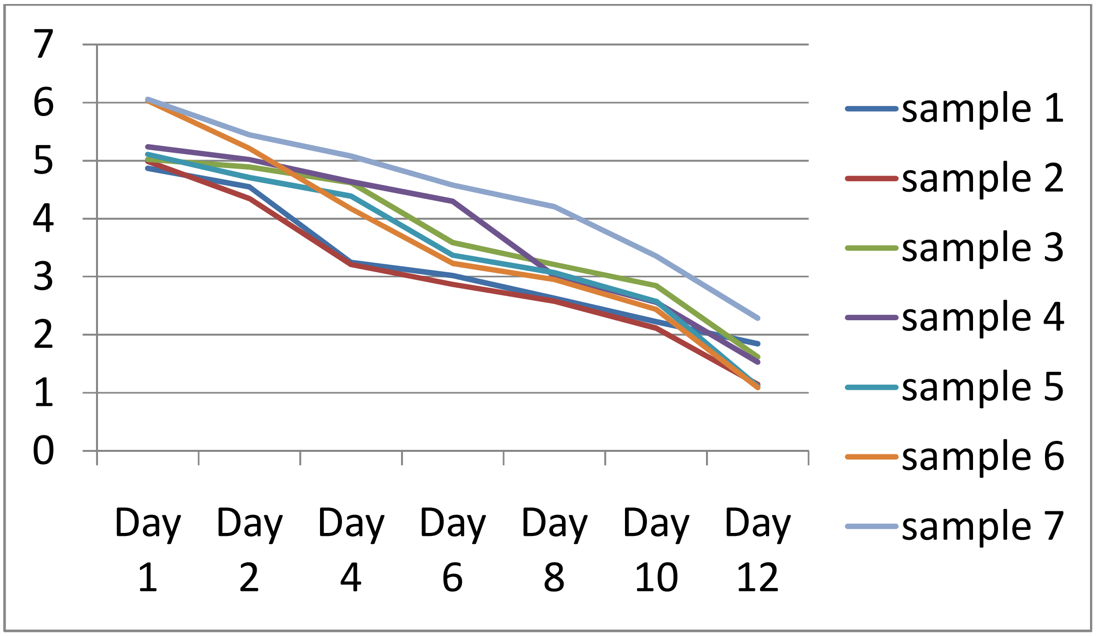
Effect of acid on the samples of bio-leather was observed as this leather is to be used in secondary packaging of food material as well as in other packaging. All the samples of bio-leather were dipped into 50 % concentration of acid. The samples were weight periodically for a period of 7 days .The percentage weight loss was observed daily until the samples completely got dissolved in the acid. Acid used in this experiment was sulphuric acid. Graph below shows the percentage weight loss of the samples in 7 days. It was found that all the samples got dissolved in the acid in 7 days.



Graph.4.4. showing effect of acid

4.9 Result of Effect of Alkali

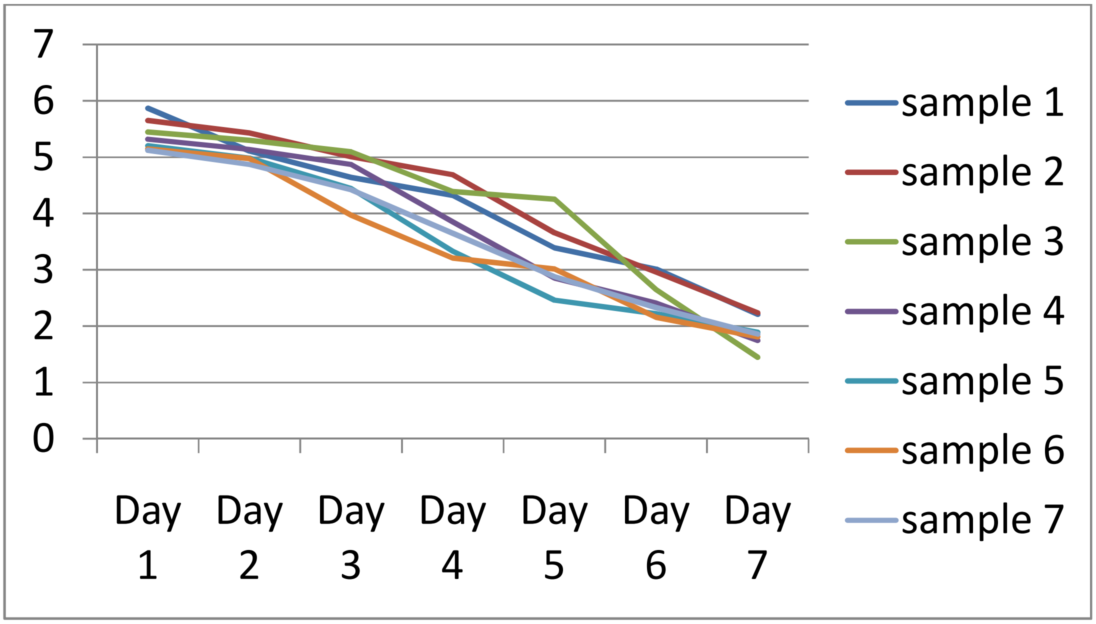
Effect of alkali on the samples of bio-leather was observed as this leather is to be used in secondary packaging of food material as well as in other packaging. All the samples of bio-leather were dipped into 50 % concentration of alkali. The samples were weight periodically for a period of 10 days .The percentage weight loss was observed daily until the samples completely got dissolved in the alkali. Alkali used in this experiment was sodium hydroxide. Graph below shows the percentage weight loss of the samples in 10 days. It was found that all the samples got dissolved in the alkali in 10 days.



Graph 4.5. showing effect of alkali

4.10 Result of Effect of Salt

Sodium Chloride salt was used for testing the effect of salt on the samples of bio-leather. Samples were dipped into salt solution for a period of 7 days , with periodic weighing every day , and its resistance to the action of salts was observed. In the graph below, weight loss of all the samples is shown and it was found that all the samples got dissolved in the solution within 7 days**.**



Graph 4.6. showing effect of salt

CHAPTER 5

SUMMARY AND CONCLUSION

The chapter deals with summary and conclusions drawn on the basis of experimental work done for the project entitled " Development of Eco leather and its Utilization in Food Packaging : A Sustainable Approach ". Currently , as ethical awareness has improved worldwide , consumers have become increasingly aware of the environmental and social issues associated with the fashion industry. Vegan fashion that does not include cruel slaughter and animal exploitation attracts much attention. The rise of interest in vegan fashion has led to an increase in interest in vegan materials, and artificial fur and leather are recognized as alternative materials to animal fur and leather. Through reflecting upon such a social phenomenon, this study compares past and present consumers' awareness of both artificial fur and leather that are alternative materials to existing animal fur and leather.

Based on the test results , following conclusions were drawn :

A lot of floral waste is generated every year in India . Though this waste can be utilised for various purposes such as making incense sticks , for making organic manure etc. But still a large amount of floral waste is dumped into rivers which may harm water bodies and aquatic life. This floral waste can also be used for making leather .this floral leather is made without any animal cruelty. And then further this leather can be used in secondary food packaging and will replace cardboard cartons , polythene bags and this leather is more durable and have more strength than presently used materials for secondary food packaging.

Various analysis were carried out during the experiment these include biodegradability , effect of acid , effect of alkali , effect of salt , hardness , tensile strength , moisture content , folding endurance.

1. Biodegradability

   Biodegradability is the capacity of biological degradation or disintegration of organic materials by living organisms by the action of microorganisms such as bacteria or fungi while getting assimilated into the natural environment .

   7 samples of eco- leather were biodegraded using two methods of biodegradation: biodegradation by composting and biodegradation by bench-scale simulated composting. In both the methods samples of eco-leather were dumped into the compost for a period of 15 days and daily samples were taken out and were weighted daily. Percentage weight loss of the samples were calculated and it was observed that all the samples of leather were degraded completely with in a period of 15 to 20 days.

2. Moisture Content

   Moisture content or water content is a reference to the amount of moisture present in a material. This value is often represented as a percentage of the materials mass (such as X% MC). Moisture content of the samples were calculated by determining weight loss upon drying and it was done by hot air oven instrument. Initial and final weight of sample before and after drying was measured and moisture content percentage of the samples were calculated using the above mentioned formula. It was found that the moisture content of sample 4 was found to be the highest which is 60%.

3. Folding Endurance

   Folding endurance test was done manually by folding the eco leather to number of times till it breaks. Folding endurance test was done on all the 7 samples and it was found that highest number of folds was of the sample 4 i.e. 950 folds.The result of number of folds of all other samples is given in the table above.

4. Effect of Acid

Effect of acid was observed on all the 7 samples of leather made .H_2SO_4 acid was used on the samples . the leather made was a biodegradable environment friendly leather so it degraded easily by acid . the samples were dip into the leather for about 7 days .

5. Effect of Alkali

After keeping the samples dipped into 50 % concentration of H_2SO_4 the sample gets completely deteriorated after 10 days . All the samples were dipped into the alkali solution and daily taken out to measure the weight then weight loss is calculated for 10 days till the time weight loss becomes zero and it was found that all the samples get deteriorated in the alkali solution within 9 to 10 days.

6. Effect of Salt

After keeping the samples dipped into 50 % concentration of NaCl the samples gets completely deteriorated after 6 days. . All the samples were dipped into the salt solution and daily taken out to measure the weight then weight loss is calculated for 7 days till the time weight loss becomes zero and it was found that all the samples get deteriorated in the alkali solution within 6 to 7 days.

7. Elongation at break

All the samples were tested for elongation by elongation tester .among all the samples , elongation percentage of sample 4 was found to be highest which is 60 %..Elongation at break test was done to ensure that how much stretching is possible in the eco leather. Elongation at break test ensured that this eco leather sample can be stretched upto 60 percent without any breaking. Thus it can be easily used for packaging purposes in various industries .

8. Tensile Strength

Tensile strength of all the 7 samples was tested by using tensile tester machine and tensile strength of sample 4 was found to be highest that is 4.2 MPa. Tensile Strength of the sample was tested by using tensile tester machine. Tensile strength was the most important parameter which is required for knowing the strength of any leather .

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