



## **GREEN PACKAGING: MUSHROOM BASED PACKAGING FOR SUSTAINABLE DEVELOPMENT IN NIGERIA (A Descriptive Perspective)**

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### **Abstract**

*The main objective of the study is to find out the importance of mushroom based packaging for sustainable development. The specific objectives are: To identify the key roles and functions of packaging, to find out why green packaging is important, to determine the benefits of mushroom packaging for sustainable development and to showcase the practical applications of mycelium. Methodologically, the paper has been written from a descriptive perspective. The key roles and functions of packaging are shown to include the following: Containment, protection and preservation, user Convenience, marketing communication, loading and transport, and identification. Green packaging is important because it is used to overcome the negative impacts of plastic packaging on the environment, humans and animals. Some of the benefits of mushroom packaging for sustainable development include the fact that they are biodegradable and strong, Can be grown into any molded shape, Can be grown with at-home packs, Consumer preference, versatile base material for the manufacture of other products, abundant, sustainable, and inexpensive, mycelium in the packaging Industry creates further income potential for farmers, it is hydrophobic and flame resistant. The practical applications include its uses in **household goods and clothing, transportation, packaging, and automotive; construction, Soil, Computing and information.** Some of the recommendations include the following: Universities and Polytechnics in Nigeria should be encouraged to partner with local farmers around them in the cultivation of mushroom that can used for researches into packaging , medicinal , manufacturing construction and textiles purposes. With the bill on the ban on the manufacturing, importation, and **use of plastic** bags, popularly called nylon bags for both commercial and*

*domestic use, It will be good for the Nigerian government to give grants to some research institutions in the country; to research on how they can use mushroom, corn starch, rice starch, sugar cane, cashew, and others to manufacture these and other products. To the manufacturers who wish to transform their traditional packaging strategy into green packaging strategy, the government should provide them tax reliefs and loan facilities.*

**Keywords:** *Green packaging. Mycelium, Mushroom, Biodegradable, Transportation, Plastic, Sustainable Development.*

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### **Introduction**

In today's marketing-driven world, a brand's recognition, perception and differentiation depends greatly upon the packaging of its products. So there is a lot of packaging and a lot of packages going around the world. Companies like Dangote group, Dufill prima foods (makers of indomie), Unilever, Nestle Nig. Plc, UAC, PZ, and others in Nigeria; and Amazon, USPS, FedEx, ship millions of packages a day. Amazon alone ships 5 billion Prime packages a year, or over 13 million packages a day (Cheng, 2019). Industrial shipments add many more packages. E-commerce packaging waste has become a bigger issue, because it has about four times as many touch-points as regular retail, and shipments are broken down into individual packages for delivery. Before the internet, this was not so (Baker, 2017).

According to The World Bank, 2.5 billion tons of waste currently generated is expected to grow by almost 3.5 billion by 2050. Plastic packaging makes up nearly half of plastic waste generated globally with only less than one fifth of it being recycled. With the media exposure about the harmful effects of plastics on the environment, there is no wonder why consumers are starting to become more aware and passionate about making a change.

All these packages flying around the globe are great for our convenience, but the amount of packaging waste that is left behind is a serious threat to our environment. Materials like cardboard boxes have low ecological impact, but many other materials, like plastic packaging and Styrofoam packing peanuts, will not biodegrade, and they are not recyclable; and consumer product packaging, such as the rings around soda cans and bottles, add even more waste.

According to the EPA, packaging contributes to an astonishing 77.9 tons of municipal solid waste per year — almost 30% of the total amount of waste; and packaging represents a staggering 65% of all household trash. *Green America* states that “*the packaging industry is responsible for 40 percent of plastic pollution and represents one-third of all trash, most of which are one-time use items such as saran wrap, grocery bags, and plastic bottles.*”

Packaging also contributes to the high costs of goods and trash disposal. Out of every \$10 spent on commodities, \$1 goes toward the cost of the packaging. That’s 10% of consumer spending going toward packaging that will ultimately end up in the garbage. Additionally, it costs about \$30 per ton to recycle trash, \$50 to transport it to the landfill and between \$65 and \$75 to incinerate it, which also releases toxic gases into the atmosphere.

With sustainability having become a mega trend and a major concern in recent years, today’s packaging innovators are continuously coming up with new ways to reduce the packaging industry’s negative impact on the environment. Recent eco-friendly innovations such as biodegradable and edible packaging not only reflect the state of our society today, but it also demonstrates the packaging industry’s ability to adapt to the ever-changing needs and concerns of consumers. On top of this, 66% of consumers say they are willing to pay premium for goods produced and sold by sustainable brands (Nielsen, 2015). That’s more than enough to make retailers and ecommerce food businesses aware of sustainability trends. So, what can be implemented to help meet these demands? Green (mushroom) packaging is the solution.

### **Objectives of the Study**

1. The main objective of the study is find out the importance of mushroom based packaging for sustainable development.
2. To identify the key roles and functions of packaging.
3. To find out why green packaging is important.
4. To determine the benefits of mushroom packaging for sustainable development.
5. To showcase the practical applications of mycelium.

### **Review of Related Literature**

#### **The Concept of Sustainable Development/ Sustainable Packaging**

The concept of sustainable development has been there for decades and as a modern concept, it was originally brought forward by the Brundtland Report in 1987 in which it was simply defined as “*development that meets the needs*

of the present world without compromising the ability of future generations to meet their own needs” (UNESCO, 2015). Sustainable development can be facilitated through five guiding principles, that is, living within environmental limits, ensuring a strong, healthy and just society, achieving a sustainable economy, promoting good governance and utilizing information communication technology as a social responsibility.

Sustainable packaging according to the sustainable packaging coalition (2017) is packaging that is:

- ❖ beneficial, safe & healthy for individuals and communities throughout its life cycle
- ❖ Meets market criteria for performance and cost
- ❖ Sourced, manufactured, transported, and recycled using renewable energy
- ❖ Optimizes the use of renewable or recycled source materials
- ❖ Manufactured using clean production technologies and best practices
- ❖ Made from materials healthy throughout the life cycle.
- ❖ Physically designed to optimize materials and energy
- ❖ Effectively recovered and utilized in biological and/or industrial closed loop cycles

### **The Concept of Product packaging**

*Packaging is the wrapping material around a consumer item that serves to contain, identify, describe, protect, display, promote and otherwise make the product marketable and keep it clean (Entrepreneur, 2017). Soroka (2002) posits that packaging is the science, art and technology of enclosing or protecting products for storage, distribution, sale, and use. Meanwhile, the New English Encyclopedia sees packaging as referring to the process of designing, evaluating, and producing packages. Packaging can be described as a coordinated system of preparing goods for transport, warehousing, logistics, sale, and end use. Higgins (2014) points out that packaging contains, protects, preserves, transports, informs and sells. In many countries it is fully integrated into government, business, and and institutional, industrial, and personal use.*

From a marketing tool point of view, Sehrawet & Kundu (2004) see packaging as a marketing tool, which allows the marketer to provide detailed

information to the consumer who may be looking to buy. Nutrition information, product measurements, instructions or the purpose of the product can help consumers decide if the product is for them.

Ronchi (2020) sees packaging as a channel for communication and adds that the fundamental criterion for the consumer purchase in 70% of cases is the eye. For this reason the package must be original but recognizable, innovative but always practical, communicative but so simple and clear. Crucial, especially for this last function, are the labels, which must give full and comprehensible information for each type of consumer (user instructions, consumer, storage etc.). Bohlmeier (2021) sees packaging as a brand ambassador in a customer's home and argues that not only does packaging play a central role in market entry and acceptance in new product categories, but it is also the first and best chance to make a sale. Lockyer (2019) sees packaging as an element of theatre because it creates suspense and excitement, plays a vital role in playing with consumer psyche .

From the point of view of publicity Reyhle (2020) opines that good packaging is also free publicity, because if the packaging is particularly attractive, buyers are more likely to take photos and share it on social media. Not paying enough attention to this aspect is a lost marketing opportunity.

An attractive packaging affects consumer perception about the quality of the product (WestRock, 2018). Therefore, the time is ripe for unique sustainable packaging structures that not only focus on differentiation on the shelf, but also contribute to the creation of the brand identity and thus give consumers an incentive to purchase the product. In a nutshell, this means that good packaging protects the product, and great packaging protects the brand (White, 2019).

Products with good and sustainable packaging aid in growing sales. So, packaging's importance cannot be over emphasized and as Stanton ( 2010) succinctly puts it, *Packaging is important in the creation of demand, protection of the product, transportation, guidelines to customers (information transmission), better storage, facilitates for carrying, identification, product differentiation and economy.* Branded packaging is an effective and important marketing tool that promotes and should be used as an important medium for brand loyalty.

## **Key Roles and Functions of Packaging**

The key roles and functions of packaging include the following:

**Containment:** Delgado-Ballest & Munuera-Alemanone opine that one of the primary and obvious objectives of the package is to contain the product. This is essential for the efficient transportation and logistics, storage and distribution of the product. In addition, containment allows repartition of the product into portions of known weight or volume and facilitates stock-keeping and merchandising.

**Protection and preservation:** in the case of foods, this is, without any doubt, the most important among the functions of packaging. By placing a more or less effective barrier between the food and the environment, the package protects the food from physical, chemical, microbial and macrobial attack from the exterior and thus has a decisive effect on the shelf life of the product. At the same time, the package protects the environment from the food, by preventing spillage, odor release, dust, and others. In thermal processing, the package dictates the type of processing and vice versa. The package, be it a metal can, a glass jar or a plastic pouch, is expected to prevent recontamination of the thermally stabilized food inside (product safety and quality) (Zeki , 2009).

**User Convenience:** Wholesalers, retailers, middlemen, warehouse keepers and consumers demand convenience in packaging. They should be light-weight and conveniently packed so as to be carried by hand. Convenience has long been and continues to be among the chief 'selling' attributes of products and packaging contributes considerably to the convenience factor in many ways (Louw & Kimber,2007). Carrying dispensing facilities, affecting consumer value, providing new solutions and consumer convenience. Adapting the size of the package to the needs of particular consumer groups (family size, individual, special sizes for food service delivery etc.) is one of the steps taken by industry to enhance product convenience through the package. Pressurized packages (for whipped cream), aerosols (for coating, flavoring, oiling etc.), easy-open and/or re-sealable packages, packages that can serve as heating utensils and as plates, cups, bowls etc.; from which the food can be eaten or drunk directly are among the convenience-driven developments of packaging technology.

**Marketing Communication:** Packaging simplifies the work of marketing and serves as a sales promotion device (Peters, 1994). Packing material in the house reminds the consumers constantly about the product. In this way, the packaging performs the role of a silent salesman (Ditcher, 1957; Welles, 1986; Phillips & Bradshaw, 1993; Wells et al., 2007). Consequently, it increases the sales of a product. Promotional material placed on the packaging is directly addressed to the consumer and it is intended to attract the potential purchaser's attention and to have a positive impact upon the purchasing decision, convincing shoppers at the point of sale (Welles, 1986; Phillips & Bradshaw, 1993; Prendergrast & Pitt, 2000; Wells et al., 2007; Lofgren, 2008). This is true both in the case of impulse purchases and high involvement products (Silayoi and Speece, 2004; Welles, 1986). Two thirds of purchasing decisions are made at the point of sale (POS) (Schoomand and Robben 1997; Connolly and Davidson, 1996) and nearly three quarters of consumers use packaging to aid their decision making process at this stage (Wells et al., 2007). This function is of subordinate significance in transport packaging. While product awareness is indeed generated along the transport chain, excessive promotion also increases the risk of theft. The quantity of information printed on a package has been increased constantly. In addition to text and graphics serving the purpose of product and brand identification and product promotion, it is considered to be the single most important factor at the point of purchase (POS) (Gray & Guthrie, 1990) providing the brand owner with the final opportunity to convince buyers to purchase their brand (McDaniel & Baker, 1977; as cited in Ampuero & Vila, 2006). The printing usually includes essential data such as list of ingredients, nutritional data, production date and/or a limit date for selling, price, a barcode and information needed for product traceability. In the near future, the package of chilled foods may carry a temperature-time indicator/integrator that, by its color, will provide information on probable mishandling of the product during storage and transportation.

**Loading and transport:** Convenient goods handling entails designing transport packaging in such a manner that it may be held, lifted, moved, set down and stowed easily, efficiently and safely (Singh & Singh, 2005). Packaging thus has a crucial impact on the efficiency of transport, handling and storage of goods. Packaging should therefore be designed to be easily

handled and to permit space-saving storage and stowage. The shape and strength of packages should be such that they may not only be stowed side by side leaving virtually no voids but may also be stowed safely one above the other.

The most efficient method of handling general cargo is to make up cargo units. The strength of the package required for stowing goods on top of each other demonstrates the close relationship between the loading and transport function and the protective function.

**Identification:** Packaging is the main way products are advertised and identified. To the manufacturer the package clearly identifies the product inside and it is usually the package that the customer recognizes when shopping (Ryan, 2011). Advertising is very important when a manufacturer launches a new or existing product. The package, through its colour scheme or logo, is what is normally identified by the customer. The package will also contain important information including ingredients and 'sell by date'. Labelling is also part of the identification of a product. A label is a carrier of information about the product. The attached label provides customers with information to aid their purchase decision or help improve the experience of using the product. According to Kumer & Kapoor (2017) labels are descriptive and can include Care and use of the product recipes or suggestion, ingredients or nutritional information, product guarantees, manufacturer name and address, weight statement warnings, contact information, price, special offers, product title, barcode and more.

### **Why Green Packaging?**

Nigeria generates more than 32 million metric tonnes of waste annually with Lagos alone producing about 10,000 metric tonnes which end up in landfills and in waterways, exacerbating the challenges of flooding and gridlocks (Ajene, 2019). The negative impacts of packaging on the environment, water and land pollution (Packaging sent to landfills, especially when made from plastics, does not degrade quickly or, in some cases takes up to 500 years, if at all. Bernau (2019) gives the following breakdown of plastic packaging degradation in years:

- **Plastic grocery bags:** 10 to 20 years
- **Plastic sandwich bags:** up to 1000 years



- **Plastic straws:** 100-500 years
- **Plastic bottles:** 450 years
- **Disposable diapers:** 450 years
- **Plastic sanitary pads:** 450 to 1000 years
- **Plastic coffee pods:** 150 to 500 years
- **Styrofoam cups:** 50 years

Chemicals from the packaging materials, including inks and dyes from labeling, leach into groundwater and soil (US EPA, 2019). The contaminated pieces eventually make their way through the food chain and into humans through ingestion of seafood.

The impact of packaging on birds and marine mammals who swallow these pieces of plastic /nylon that do not decompose is terrible. This means that fishing nets lost in the ocean, called ghost nets, continue to catch fish for many years. Because of this, hundreds of millions of marine animals are killed or injured every year due to fishing nets pollution (Ettinger, 2020). Air pollution from food packaging (packaging waste that is not recycled or composted is typically landfilled or incinerated and this produces air emissions, including greenhouse gases) (Marsh, Kenneth and Bugusu, Betty, 2007). Landfills emit ammonia and hydrogen sulfide and incinerators emit mercury, lead, hydrogen chloride, sulfur dioxides, nitrous oxides and particulates that are bad for humans. **The situation was so bad that The World Economic Forum and Ellen MacArthur Foundation (2016) have a report that says “There will be more plastic than fish in the world’s oceans by 2050 and if the current trend continues, oceans will contain one ton of plastic for every three tons of fish in 2025; unless more recycling takes place. This is a freightening situation.**

In order to look out for the welfare of our species and the others that inhabit this planet, we need to look for viable alternatives to plastics, styrofoam, cardboard, and paper used in the supply chain process that are harmful to the environment. Green packaging is the solution. Being responsible world citizens, we are duty-bound to reduce our carbon footprint and figure out a way to slowly eliminate plastic from our systems (Plastic is not the only culprit, but it is the major one).

In the recent past attempts were made by companies and individuals to reduce the effect of product packages on the environment, by direct elimination,

innovative elimination, refills, return and reuse, plastic recycling, composting, and substituting materials (Thornton, 2021). These attempts have not really yielded much fruits, hence the need for green packaging.

The first and foremost reason to embrace green packaging is that it is the right thing to do. We save the earth through meaningful efforts. Adopting a green packaging strategy makes sense on multiple fronts, from reducing harm to the environment, humans and other living creatures to building brand loyalty. Businesses are becoming aware of how sustainable efforts can work to their advantage and are coming on board. There is indeed no better time to go green than now. Besides that, 85% of consumers seem to want packaging that is recyclable or reusable, 66% of consumers prefer to buy products in packaging made from plant-based materials, and 66% of consumers prefer to buy products in packaging that is mostly made of paper (*Eco Focus Trend Study, 2018*).

### **Concept of Green Packaging**

Green packaging, also known as sustainable packaging, eco-friendly packaging, and environmentally - friendly packaging , is packaging that can be biodegradable (but preferably compostable), recyclable, reusable, non-toxic, made from recycled products, based in biomass or natural products or manufactured through low-impact means (Cameron,2018).Green packaging according to Forbes (2020) is packaging whose ingredients are 100% recycled or raw materials , production process is minimized including the supply chain and carbon footprint and has reusability by creating a circular economy around the packaging, extending its lifecycle and usability. Rooland (2019) defines eco-friendly packaging as any packaging that is easy to recycle, safe for individuals and the environment, and is made out of recycled materials. It uses materials and manufacturing practices with minimal impact on energy consumption and natural resources. All the experts agree that for packaging to be sustainable, it has to be:

- Biodegradable/ compostable.
- Recyclable, reusable or be manufactured with recycled products.
- Non-toxic materials.
- Based on biomass or natural products.

## **Green Packaging Materials for Sustainable Development**

Green packaging uses materials and manufacturing techniques to diminish energy use and reduce the harmful impacts of packaging on the environment. Green packing solutions often include biodegradable and recyclable materials in preference to materials like plastic and Styrofoam; and green manufacturing processes take steps to reduce their power output and diminish the number of greenhouse emissions they produce. Some of these materials according to EcoBahn (2020) are as follows:

- **Cornstarch/Rice starch / Starch-Based Biomaterial**
- **Other Plant-Based Biomaterials**
- **Biodegradable Packing Peanuts**
- **Corrugated Bubble Wrap**
- **Mushroom Based Packaging**
- **Recycled Cardboard and Paper**
- **Post-Consumer Recycled Plastics**
- **Organic Fabrics**

## **Mushroom Packaging for Sustainable Development**

Mushroom packaging is made using the vegetative part of a mushroom fungus along with crop waste to form a bioplastic. The manufacturing process begins by mixing fungus sprouts, or mycelia, with seedlings or other residues from agriculture. Sidhu (2020) affirms that **Mycelet consists of a network of wire-like cells that act as a natural adhesive.** Without the need for either light, water or chemical additives, the mycelium grows by and around the residues to the desired packaging form. After one week, growth is stopped by a drying and heat treatment process. **Mushroom packaging consists of 100 percent biodegradable and renewable material that can be recycled directly in and by nature, unlike styrofoam. Mushroom packaging therefore contributes to “up-cycling” by providing new value to agricultural waste that otherwise has few other uses and low economic value.**

## **Packaging and the Circular Economy**

In a circular economy, products are reused. Products which cannot be reused are recycled by chemical or mechanical processes, or through biological

processes such as composting. Circular packaging solutions incorporate the principles of the circular economy and integrate seamlessly into sustainability efforts.

Fontaine (2014) argues that in the packaging sector, the circular economy model is about more than just recycling. It handles all stages of a product's lifecycle, namely: its design, production, distribution and use, but also its recovery. It includes notions such as local integration and proximity. It also includes saving resources (materials, water, and energy), mostly through:

- Conceiving the product/packaging combination in an eco-friendly way
- Using resources parsimoniously.
- Reusing packaging, especially on a business-to-business basis; preventing packaging waste
- Preventing product waste Preventing waste by improving recyclability of products and packaging
- Reusing materials to optimize material flow. It also includes every initiative to change people's behavior to improve packaging.

It is estimated that the circular economy could offer up to \$4.5 trillion in global economic benefits by 2030, alongside environmental benefits such as lower emissions and better land use. (Van Houten, 2019).

**Fig. 1: Packaging and the Circular Economy**



Source:

<https://circulareconomy.europa.eu/platform/sites/default/files/packaging-and-circular-economy-final-report-en-september-2014.pdf>

### Benefits of Mushroom Packaging for sustainable development

Ecobahn (2020) and Lawson (2020) argue that the following benefits of mushroom packaging are real.

- **Biodegradable and strong** – consumer demand is increasingly moving towards eco-friendly materials, but strength and reliability are still necessary features of

most products. Mycelium's ability to remain strong as an organic, biodegradable product is a major advantage over other materials.

- Can be grown into **any molded shape** – this makes production simple, at least in terms of product specifications. Growing exactly the right amount of material needed for any product is advantageous in eliminating waste and improving efficiency.
- **Can be grown with at-home packs** – this is great for small businesses that need exact specifications and is useful for any company that wants to have more control over raw materials used in their products.
- **Consumer preference** – mycelium has an inherent advantage over polystyrene foam due to its sustainable nature. It is also cost-competitive and equally as effective as packaging material or as a base for other products. This makes it preferential for anybody seeking compostable or biodegradable products.
- **Versatile base material** – several useful products can be made from mycelium's foam base, with an extensive list of applications and possibilities that range from outdoor jackets to insoles and shoes.
- **Abundant, sustainable, and inexpensive** – the creation of mycelium foam uses farm waste, which will always be readily available all over the world. Mycelium hyphae are also renewable and plentiful – and the entire production of mycelium foam is inexpensive and cost-competitive with polystyrene foam.
- **Mycelium in the Packaging Industry** creates further income potential for farmers.
- **Hydrophobic:** The Myco Composite is water-resistant, meaning products are protected from the rain and other elements.
- **Rigorously tested:** Magical Mushroom have tested their material thoroughly, knowing that it protects products against heat, cold, and impact.
- **Flame resistant:** The resulting MycoComposite is a poor ignition source, meaning it is flame resistant.

### **Practical applications for Mycelium (Mushroom)**

Flagel (2020) and Hugo (2016) affirm that there are surprising new uses for mushrooms, not only for making packaging materials but also in fashion, medicine, furniture and others. They are as below:

**Coffins** made by Dutch startup Loop that are not only biodegradable but also help biodegrade the bodies laid to rest inside.

- **Flooring and acoustic tiles**, which are sold by Italian interior design products
- **Leather.** MYCL, based in Bandung, Indonesia, partnered with local apparel brand BRODO, to launch sneakers, sandals, wallets, luggage tags and watch straps made of its mycelium-based leather Mylea last year.

Crosser (2021) and cbc Radio-canada (2021) argue that applications for mycelium are broad and impactful. Below, are highlighted a few of the major categories of seen research or commercialization so far.

- **Meat without animals (alternative proteins).**
  - **“Plant-based” meat.** Filamentous fungi have been used to make semi-structured ground meat analogs-creating structured whole cuts like steak, fish fillets, and bacon.  
**Cultivated meat.** Cell-based meat is quickly becoming a reality, but 3D structured products remains a technological challenge. Mycelium-based scaffolding is one solution being explored and it could also be used to grow organs or tissues for medical use.
- **Household goods and clothing.**
  - **Furniture.** Among the first applications of mycelium to emerge were high-value 3D objects like chairs, lamps, statues, and art pieces made by avant garde designers. Really, anyone can grow whatever shape they want if you have the right mold (which can be 3D printed).
  - **Mycelium chair** developed by designer Erik Klarenbeek and the University of Wageningen in 2013.
  - **Textiles.** Fashion also sprouted early. Mycelium “leather” is extremely promising, referred to as fall 2020’s hottest fashion trend by the New York Times, with the likes of Adidas, Kering, and lululemon developing products. British designer Stella McCartney on March 18, 2021 made with Mylo, a leather substitute grown from fungi, which can be treated to have different leather-like colours and textures.
- **Transportation, packaging, & automotive.**
  - **Styrofoam.** Mushrooms may seriously change the way goods are packaged and transported. Mycelium can feed on cheap,

lightweight substrates like grasses and is the best hope for replacing polystyrene which alongside plastic comprises 90% of marine debris.

- **Automotive.** Ford has nine patents relating to filamentous fungi, mostly for aesthetic and interior molding components, according to this fantastic patent analysis conducted by Mycorena. Mycelium also touches the roads themselves. Self-paving, self-repairing, or even self-designing roads.

- **Construction.**

- **Materials.** Self-repairing concrete foundations are just the beginning. Sustainable insulation, composite materials (novel particle board, drywall, etc.), and even acoustic panels are in development.
- **Buildings.** It is entirely possible that entire structures could be built with mycelium, perhaps even *grown*. This field, called myco-architecture, is even being researched by NASA as a way to build habitats on the Moon and Mars (not to mention mining materials from space rock).

**Soil.** Nearly all plants evolved symbiotically with fungi, which provide the plant's roots with minerals in exchange for sugars (a *mycorrhizal* relationship). That fundamental relationship has mostly been ignored in favor of chemically-supplemented, frequently-tilled industrial mono-cropping, but producers seem to be increasingly turning to providers like MycoBloom to introduce the mycelium back into the soils. Mycelium can also break down petroleum, pesticides, and heavy metals which is leading to a few companies working on *mycoremediation*.

- **Computing & Information.** The aforementioned mycorrhizal networks have been shown to connect plants to each other as a way to send nutrients and information (e.g. when one plant is being infested by insects it warns others, via electrical impulses and/or chemicals) in what has been called the "wood wide web." Perhaps this is what inspired the exploration of fungi-based biocomputing. Ecovative was granted a patent in 2016 for electric circuits composed of mycelium.
- **Others.** Unique applications abound and organizations like the University of Utrecht Westerdijk Fungal Biodiversity Institute are helping to uncover more.

- **DELL:** bamboo packaging and mushroom packaging for their servers.
- **Procter Gamble:** sugar cane-based polyethylene containers
- **Coca-Cola:** bottles contain at least 30% plant-based material
- **NEC:** 70% bioplastic in mobile phone cases made out of cashew nut shells and oil
- **Whole Foods:** fiber-based biodegradable food-to-go containers
- **Macy's:** 100% biodegradable packaging materials for online purchase shipments

### **Conclusion and Recommendations**

The paper set out to find the importance of green packaging (mushroom based packaging) for sustainable development. Packaging is important to business organizations, individuals and even to government because of the various roles and functions it performs as can be seen in the literature reviewed. But using packaging materials that are harmful ((as shown in the section on why green packaging?)) to humans, animals and the environment and tending to sack inhabitants of the earth from their peaceful habitation and sure dwellings that God put them in, is something else entirely. The answer to saving the earth is practicing sustainability in all we do especially in terms of packaging. The solution to this packaging pandemic is green packaging, which includes the use of materials that are biodegradable/ compostable, recyclable, reusable or are manufactured with recycled products, non-toxic , based on biomass or natural products which are earth, human, and animal friendly. Mushroom (mycelium) is one of these materials. The section on practical applications shows that this has been done and more can still be done using mycelium (mushroom). Let us not forget, the words of Steven Irwin “*The single biggest threat to our planet is the destruction of habitat and along the way loss of precious wildlife. We need to reach a balance where people, habitat, and wildlife can co-exist – if we don’t everyone loses ... one day* ((22 February 1962 – 4 September 2006). *When we heal the Earth, we heal ourselves.*” (David Orr).

### **Recommendations**

1. Universities and Polytechnics in Nigeria should be encouraged to partner with local farmers around them in the cultivation of mushroom that can used



for researches into packaging , medicinal , manufacturing construction and textiles purposes . There are over 5million species of mushroom. This discovery of mycelium was made by two polytechnic students in New York.

2. Cooperative farming societies can be encouraged by the various governments in Nigeria in the production of large scale mushroom that can be bought by governments and research institutes for further research.

3. With the bill on the ban on the manufacturing, importation, and **use** of **plastic** bags, popularly called nylon bags for both commercial and domestic use, It will be good for the Nigerian government to give grants to some research institutions in the country; to research on how they can use mushroom, corn starch, rice starch, sugar cane, cashew, and others to manufacture these and other products .This has been in some countries of the world.

4. If the Nigerian government is serious, every local government can create days and places where the officials can buy agricultural waste from farmers that can be used for the production of mycelium based packaging.

4. To the manufacturers who wish to transform their traditional packaging strategy into green packaging strategy, the government should provide them tax reliefs and loan facilities.

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