Corn & Rice Starch-based Bioplastics: An alternative material Nature Friendly Biodegradable Head Caps

A research proposal

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***Abstract*— Here we propose the use of Corn and Rice Starch as a material of choice to manufacture head caps. Apart from Corn and Rice Starch we can also use chitosan, cellulose and protein extracted from renewable biomass, but in our research proposal we will restrict our discussion to Corn and Rice Starch, to which we can add other supplementary ingredients which would further improve the properties of the finished product in terms of its comfort during use and, it is physical appearance. One of the most important advantages of these caps is that they degrade to water and carbon dioxide on their own when not disposed properly, thereby not posing any serious environmental threat. We have chosen Corn and Rice Starch because of its easy availability, low cost, as well as its ability to degrade to relatively harmless products. Our prime goal here is to basically come up with a product that causes least damage to the surroundings. In addition to this other parameter under consideration is eased to manufacture and final cost of the head caps. These bioplastics could prove to be a revolution in the green plastic world. The property of degradability is what makes them unique and separates them from the rest of the plastics. They certainly would not cause any pollution as their composition is completely from biomass which comprises of organic matter only and is free of toxic materials. It also rules out the possibility of damage to the marine flora and fauna as they comprise biomass only. This research proposal also involves surveys and statistical analysis of the current situation where we are using synthetic plastic and how scenario changes as we move to bioplastics as an alternative approach. Here we will also discuss the future outcomes and the pros and cons of our product.**

***Index Terms*— Cellulose, Bioplastics, Environment-friendly, Rice-starch, Polymerization, Biomass**

I. Rationale and Gap Analysis

Plastics play a vital role in household appliances as well as industries. The annual production of petroleum-based plastics was more than 300 million tons until 2015.[1] During manufacture of plastic products, emission of carbon and many dangerous gases into the atmosphere possesses great environmental concerns. One of the plastic products prevalently used worldwide are head caps used by medical professionals.[2] An alternative to this could be Corn and Rice Starch based Bioplastics as a raw material to make head caps. These bioplastics are derived from edible and natural biomass which possibly cause no harm to the human body. Due to the negative environmental impact of synthetic plastics, the development of biodegradable plastics is essential today. Although synthetic plastic is easy to manufacture and cost effective, it is non-degradability serves the basis to look for environment friendly substitutes.[3] Hence efforts are taken to gradually reduce our dependence on synthetic plastics and switch over to eco-friendly options.

II. Objectives

1) To promote eco-friendly and renewable methods of production and application of bioplastics derived from natural origin.
2) To mitigate the adverse effects of synthetic plastics which are non-biodegradable and thereby improve the carbon footprint drastically.
3) To achieve a breakthrough in medical as well as textile industry and to foster production of 100% eco-friendly products.
4) To create an ideal chain of management such that every by-product can be incorporated into the chain of production and avoid production of wastes.

III. Research Methodology

Fig. 1: Equipment for separation

Corn starch plastic is an alternative product to the infamous petroleum-based plastic. Through the incorporation of modern biotechnology, lactic acid is extracted from starchy corn kernels. Polymerization is carried out to produce polylactic acid polymer. Our aim is to separate starch, protein, and fiber from corn. [6]

The steps involved in the same are:

1) Cleaning and Inspection- Approximately 70 percent of the kernel is starch, about 10 percent is protein and two percent is fiber (from the hull). It is the goal of the corn refining process to separate each component and then further refine it into specific products. [7]
2) Steeping- During steeping, the kernels absorb water leading to increase in their moisture levels and more than doubling in size. The addition of 0.1 percent sulphur dioxide to the water prevents excessive bacterial growth in the warm environment. As the corn swells and softens, the mild acidity of the steep water begins to loosen the gluten bonds within the corn and release the starch. After steeping, the corn is coarsely ground to break the germ loose from other components. The ground corn, in a water slurry, flows to the germ separators. [8]
3) Germ Separation- Cyclone separators spin the low-density corn germ out of the slurry. The germs, containing about 85 percent of corn's oil are pumped onto screens and washed repeatedly to remove any starch left in the mixture. A combination of mechanical and solvent processes extracts the oil from the germ. The oil is then refined and filtered into finished corn oil.[9]
4) Fine Grinding & Screening- The corn and water slurry leaves the germ separator for a second, then grinding in an impact or attrition-impact mill to release the starch and gluten from the fiber in the kernel. The suspension of starch, gluten, and fiber flows over fixed concave screens, which catch fiber but allow starch and gluten to pass through. The starch-gluten suspension, called mill starch, is piped to the starch separators. [10]
5) Starch Separation- Gluten has a lower density than starch. By passing mill starch through a centrifuge, the gluten is readily spun out. The starch after processing is typically more than 99.5 percent pure. Most of the starch is converted into corn syrups and glucose.[11]

The starch which is around 99.5% pure separated from all remnants of gluten, germ etc. is further acted upon by enzymes or acid and converted to simple sugars like dextrose. This dextrose further undergoes the process of fermentation where it is acted upon by bacterial /yeast culture like Lactobacillus bulgaricus or Streptococcus thermophilus, both together found in yoghurt and fermented to Lactic acid. [12] Many molecules of lactic acid come together and polymerize into polylactic acid (PLA). This with other excipients like distilled water, Glycerol and white vinegar when stirred in a saucepan by heating at low temperature will form a consistent mixture and the food color of any choice can be incorporated. This mixture in the form of fibers can be further incarnated to give the desired headgear. [13]

IV. Preliminary Survey

The source for the desired product depends upon the properties expected in the product. Henceforth, the constituent and its amount present in the source determines the quality of the product. Common sources of starch include rice, maize, wheat, potatoes and cassava. It is composed of two sorts of macromolecule: amylose, which is a sparsely branched carbohydrate; and amylopectin, which is highly branched with a high molecular weight. Different plant species and varieties tend to have different proportions of amylose and amylopectin, as well as varying degrees of granule diameter. This can affect the degree of processing required and the properties of the final product. The common availability of this feedstock has generated considerable interest in the potential for starch-based products to replace conventional plastics. [14]

Table 1 Composition of different starches[15]

Starch	Amylose content (%)	Amylopectin (%)	Granular diameter (micron)
Wheat	26-27	72-73	25
Maize	26-28	71-73	15
Waxy starch	<1	99	15
Amylomaize	50-80	20-50	10
Potato	20-25	74-79	40-100
Rice	25-30	65-70	3-5

As per survey, the production of corn and rice starch-based bioplastic head gears for doctors and other health professionals is a better alternative. It is found that these products would have the following advantages over plastic head gears:

- ✓ Potentially a much lower carbon footprint
- ✓ Lower energy costs in manufacturing
- ✓ Do not use scarce crude oil
- ✓ Reduction in litter and improved composability from using biodegradable bioplastics [16]

The physical properties of bioplastics like molecular weight, dimensions, thickness, tensile elasticity, and firmness make them more reliable for production on larger scales. Due to the impact of Covid-19, the use of head gears by doctors and other health professionals has increased drastically. Considering this, switching the material used for making head gears with corn and rice starch-based bioplastics becomes a necessity. [17]

V. Expected Outcomes

However lightweight and durable, plastics have become a main causative of environmental pollution, thus bioplastics can be used in the place of synthetic plastics. On testing corn and rice starch-based bioplastic products, it was found that they exhibited the following properties:

1. **Tensile properties**- Tensile strength is the amount of maximum strength needed to break the bioplastics film. The starch crosslinking of ether or ester linkages amongst hydroxyl (-OH) clusters in starch molecules improved mechanical properties, due to the density increased by crosslinking. [18]
2. **Bioplastic thickness**- The thickness of the bioplastics is measured at 10 different places using a thickness gauge, and the average is calculated. The thickness value of corn starch films was approximately 0.15 mm. The average thickness of the bioplastics is 250 microns. [19]
3. **Moisture content**- The hydrophilic compounds would increase the films' solubility. However, the hydrophobic compounds would decrease it. The solubility of all the starch films followed the same tendency as per the expectation, while the hydrophilicity of the film decreases with the further addition of rice starch. Hence, lower the moisture content, longer the shelf-life.
4. **Biodegradability properties**- From the SEM analysis, it could be concluded that the bioplastics prepared from starch are biodegradable. The environmental factors such as temperature, moisture and biological activity would affect the rate of degradation. [20]

Properties	Corn Starch	Rice Starch
Moisture content (in %)	10.82	11.24
Ash content (in %)	0.32	0.29
Protein (in %)	0.38	0.43
Fat (in %)	0.32	0.34
Fiber (in %)	0.10	0.12
Amylose (in %)	29.4	33.6
Density (g/ml)	1.356	1.282
pH	6.72	6.82

Fig. 2 Corn & rice starch properties (in %)[18]

The study showed that the corn and rice starch-based products have better biodegradability than the existing plastic materials. The cost of production is moderate and relatively easy. The total amount of plastic waste arising every year is estimated to be 5.9 million tons. All these plastics are dumped intentionally or unintentionally and cause major environmental hazards. They are not biodegradable and harms the ecosystem. Bioplastics do not cause any environmental and health hazards. [21]

VI. Benefits to the Society

The uses of polylactic acid are varied and starch-based plastics can be used in a variety of applications. It is increasingly being used in several markets from packaging, automotive, catering products, consumer electronics, agriculture and horticulture, toys, and textiles. [22]

A multitude of products are currently being made from corn plastic and more are continuously being developed.

- It can be used to make biodegradable packaging materials, food bags and food packaging materials.
- Take out and disposable plates, bowls, cups, cutlery etc.
- Also used in medical implants and surgical devices such as sutures, ligatures and meshes. [23]

Advantages of using corn starch polymers:

- ✓ Corn plastic packaging or items made from corn plastic, will decompose within two months of being in a high humidity composting environment, at a temperature of above 60° Celsius or 140° Fahrenheit.
- ✓ Bioplastics will not emit toxic gasses when it is incinerated as it contains no toxins.
- ✓ A reduction of 68% of greenhouse gas emissions, compared with production of conventional fossil fuel plastic, so much less greenhouse gases are emitted. [24]
- ✓ Corn starch plastic needs 65% less energy to be produced than conventional petroleum-based plastics.
- ✓ Polylactic acid plastic is cost competitive with conventional plastic.
- ✓ Using corn starch polymers to make plastic have no danger of explosion during the production process as is the case with petroleum, so it is much safer to work with.
- ✓ The bio plastic is free of BPA's and phthalate, so no worries about endocrine disruption.
- ✓ Corn starch packaging has less static electricity than synthetically made packaging materials. [25]

VII. Cost Benefit Analysis

For production of 1kg PLA, 1.62 kg corn grain with 0.81 kg of corn stover (husk, cob) is required. Increasing amount of husk by 20-30% is preferable as large-scale use of corn would impose environmental stress. The husk is almost discarded but can be used for this purpose. This with other excipients would give 80-90 head gears of uniform size, each costing ₹10-12/- The product is reusable for maximum 5 uses being inexpensive and reproducible. [26]

Table 2: Cost analysis with respect to procedure[27]

Process	Equipment or chemical used	Function of equipment or chemical	Conventional cost (%)	Enzymatic cost (%)
Harvesting	Trucks, Railcars	Transportation of crops to labs, industries	8.2	8.7
Steeping	A large stainless-steel tank	Cleaning, inspection to check the quality & soaking of bushels to increase moisture content	22.3	10.7
Coarsing	Cyclone separator, Starch separator	Separation of Germ and starch	13.5	14.4
Attrition & impact	Impact mill	Reduce particle size	12.0	5.0
Excess water removal	Hydroclones	Prevent microbial degradation	3.1	3.9
Obtain 99.5% pure Starch	Centrifugation	Removal of remnants of Gluten, Germ	27.1	30.0
Enzymatic reaction	Enzymes /acids	Starch to dextrose (sugar)	7.2	14.5
Fermentation	Bacterial /yeast culture	Sugar to lactic acid	6.6	12.8

VIII. Conclusion and Future Scope

The bio-based products are in an alarming need in the present-day scenario because they ensure environmental protection in future. The raw materials used to get corn starch polymers are inexpensive and easy to produce. This is great way to reduce a carbon footprint. The uses of polylactic acid are diverse and have a lower environmental footprint than fossil fuel plastic.

The advent of corn starch-based bioplastics allows everyone to switch to a more sustainable alternative and a greener option. [28]

The only risk factor is that decomposition of PLA pellets is time consuming which requires their melting to various forms and can be spun in fiber but this can also be eliminated by treating them with strong concentrated solutions. This product with many pros and a very few cons will have a great future in the field of healthcare. The requirement of PPE kits has increased in this era of pandemic. Initially, there was an acute shortage of PPE kits. They can also be manufactured from corn, corn husk and rice starch. Since husk is anyway a waste product it does not add to initial cost of the raw material and cost of one PPE kit can further be reduced. [29]

IX. SWOT Analysis

1) **Strengths**
- Utilizes renewable natural resources
- Starch crops are readily available in most developing and developed countries, and are staple in many countries in Asia, Africa, and South America
- Can be composted in an industrial facility or decomposed by anaerobic digestion at end of life.
- Rate of biodegradation in the environment is significantly faster than for conventional synthetic polymers. [30]

2) **Weakness**
- Biocides and artificial fertilizers may be used on commercial crops, resulting in risks to human health and the environment
- Substitution for conventional polymers is limited by intrinsic properties of the material
- Products composed of TPS may remain in the aquatic environment for several years before degrading, posing a risk to social well-being and the environment. [31]

3) **Opportunities**
- Expanded utilization of renewable natural resources
- Development of social and economic independence in rural areas
- Substitution for single-use consumer products such as shopping bags. [32]

4) **Threats**
- Loss of habitat and biodiversity
- Intensification of production will drive greater use of biocides and artificial fertilizers increasing risks to human health and the environment
- Use of agricultural land for non-food use may drive up prices and impact food security. [33]

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