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Mechanical Properties of Compression Molded Natural Fiber Composites

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Abstract **- Plastic has emerged as a major source of pollution due to its non-decomposable properties. But in the packaging industry, it seems almost impossible to reach the product to people without the product packaging in plastics. Bottles of drinking beverages spread a lot of pollution in the form of garbage which is also not decomposable and their recycling process is also not easy. Companies like Coca-Cola and PepsiCo have decided that they will soon bring their drinking beverages to the market with bottles that will be decomposable and edible also. The most suitable material for making these bottles is rice paper, milk protein and casein composite material. In this paper, we will go through the production process and characterization of composites which are used in beverage items.**

Keywords **– Fiber Composites, Sugarcane, Milk Protein, Casien.**

1. Introduction

In recent times, the use of natural composites fiber has grown exponentially everywhere. Natural fiber can be used in packaging material by minimize these weaknesses by mixing different fillers. Every year 20 million tons of plastic items are made in India alone and this number is increasing every day [1,2]. The way the government has banned polythene bags, it clearly shows how polythene bags are harming our environment and how big a problem the pollution caused by it is. We all know that plastic bags take a long time to decompose and the pollution caused due to this has the biggest effect on animals like cows and buffaloes apart from humans who eat plastic bags while grazing and get sick even dies. We know how a lot of food wrapping material gets accumulated in our homes during parties, which causes a lot of problems for us. Looking at all these things, the researcher has advised the governor and the people to use natural fiber as a carry bag. Natural fiber gets easily decomposed and if eaten by animals, there is no danger to the life of animals because animals easily digest cellulose. Researchers have told edible polymers in 4 categories -: hydrocolloids, polypeptides, lipids, composite edible polymers. In this paper we will discuss how to use edible natural fiber as a bottle so that the beverage industry can stop using plastic bottles, as well as we will try to find out best manufacturing process of edible natural fiber, testing of natural fiber and properties of natural fiber. The resistance of natural fiber to wet environment condition remains poor and loses its strength, as well as the problem of smell coming from natural fiber is also in front, we will talk about how all these error can be removed [3,4].

The packaging material and bottles are very easy to recycle since they are made from natural fibers. Soft gel capsules, hard gel capsules, microcapsules, by using all these materials layer by layer, we can make a better packaging material and bottles which are also best for recycling. The packaging

material and bottles are also very easy to recycle since they are made from natural fibers. Soft gel capsules, hard gel capsules, microcapsules, by using all these materials layer by layer, we can make a better packaging material and bottles which are also best for recycling. Due to continuous research, consumer demand in this field also increased very fast. Edible natural composite material cannot completely replace conventional packaging, but we can use edible composite material as primary package and conventional material as secondary package. Secondary packages can be used for additional protection that can protect the food item from the atmosphere and contamination by foreign particles and micro-organisms. There are different types of film-forming material which enhance the properties of edible natural fiber-: Protein, Wheat gluten, Corn zein, Soy protein isolate, Collagen and gelatin, Milk Protein, Fish protein, Egg white protein, Keratin, Peanut protein, Rice protein, Pea protein and Sorghum protein [5]. We talk about Milk Protein and Casein as filler or protective layer to improve the mechanical properties and aesthetic look of sugarcane fiber. Milk protein and casein are the edible polymer and best replacement of the plastic foil which provides a good barrier to moisture and micro-organism when use with sugarcane fiber, they should accomplish a number of necessities such as biochemical, physicochemical, and microbial stabilities [6]. In this review paper, we will try to highlight the challenges involved in making and using edible composite materials.

2. Material and Method

Material property prediction plays a pivotal role in materials science and engineering, enabling researchers to understand and anticipate the behavior of materials under different conditions. Accurate predictions are crucial for designing and optimizing materials for specific applications, ranging from structural materials in aerospace to electronic components in microelectronics. Several computational methods are employed for material property prediction, each offering unique insights into different aspects of a material's behavior.

The reinforced composites comprised of sugar cane fiber as the reinforcing agent, and casein as hardener. Both fibers are bought from Indian market. Sugar cane fiber bundles were collected from sugarcane by chemically extracted method. We can collect Sugar cane fiber bundles from the several sugar mills in India. Casein is separated from milk by the help of special bacterial method which produce lactic acid. After mix with alkaline solutions and drying, casein becomes a sticky substance that can be used as hardener and filler agent with sugar cane fiber in the manufacturing process of edible beverage bottles [17]. Caseins are used in glues, the coating of paper and in paints due to its sticky property. To improve the adhesive bonding between Sugarcane fiber and casein, alkaline and acidic treatments were used and modify the surface of sugarcane fiber. The samples are made and fabricated by the hot press molding technique. Initially, sugar cane fiber and casein are mixed with resin extract from coniferous trees at different weight ratios as sugarcane: casein: resin (50:30:20, 60:20:20, 70:20:10) while overall fibre loading maintain to 70%. The fibers and resin mixture placed in the die of bottle and cured at the temperature of 400k for 15 min under pressure of 25 bars. After the sample preparation we can perform different types of test on sample to find out their mechanical properties.

Features Require in Edible Composite Natural Fiber for Bottle Manufacturing:

1. Protection against environment: Permeability is the important properties to protect food against ambient temperature of environment which is available inside bottles made by edible composite natural fiber material [7]. Observation of permeability should be conducted in the specific conditions.

2. Protection against moisture: Due to moisture exchange in packaged food can result in bacterial & fungal growth, unwanted textural changes, and chemical reaction. This feature highly required in manufacturing of edible beverage bottles. Lipids and hydrophobic compound used to make protective layer against moisture [8].

3. Aroma: Due to the organic compound, the aroma of the food product goes away and foul smell comes in the food product during storage and distribution. The casein-based protein edible film makes the excellent protection to organic compound and O2 barrier for food product [9].

4. Protection against oil: Phosphoproteins mostly casein gives resistance against grease or oil penetration in the edible fiber.

5. Protection against mass to transfer during food processing: Edible polymer coatings on drink product container can prevent water-soluble ingredient loss.

Table 1. Tensile strength and elongation properties of edible polymers [10, 11]

Edible Polymers	Tensile Strength in MPa	Elongation at break in %
Polyvinylidene chloride	65-75	18-23
Polyethylene terephthalate	81-85	19-25
Oriented polypropylene	50-60	73-100
Low density polyethylene	16-18	More than 100
Mung bean	5.70-6.51	32-40
Peanut Protein	3-4	147-150
Whey protein	2.5-3.0	15-18
Lentil protein	4-5	58-70
Soy protein	3.7-4.5	152-160
Starch	35-46	1.7-3.4
Gelatin	25-140	7-22
Chitosan	10-100	20-80
Collagen	1-70	10-70
Cellulose derivatives	44-65	10-50

Film-Forming Materials: Various materials are used in edible packaging are classified ashydrocolloids, polypeptides, lipids, composite edible polymers. Different types of enhancers are used to improve the physical properties or functionality of the films. Details of some natural fiber that form films are given below-:

1. Proteins: Protein-based films have very good mechanical and optical properties. They maintain good resistance to oxygen, carbon dioxide and aroma, but have high water vapor permeability. Their mechanical properties are affected due to moisture. We can improve

the film-forming capacity of proteins by enzymatic treatment, salt addition, intermolecular cross-linking, or by manipulating the pH value [12]. To increase the physical properties, we can add nanoparticles to proteins or take the help of heat treatment.

2. Wheat gluten: Gluten is a type of protein which is naturally found in wheat. Wheat gluten is the composition of gliadins and glutenins [13]. Its moisture, gas and solvent resistant properties make it an ideal material for making edible fibers that can be used as packaging materials.
3. Corn zein: The best quality of corn zein is that it is insoluble in water and anhydrous alcohols. Zein is a material that has found considerable success as a packaging material in the food industry. Zein is used in the manufacture of packets of candies, packets of confectionery products, and in the coating of pharmaceutical tablets [14].
4. Soy protein: The main quality of soy protein is that the packaging material made using it does not allow the flavor of drinks and food products to end. Soy protein also has antioxidant and antimicrobial properties that allow beverages and food items to remain fresh [15].
5. Collagen and gelatin: Collagen and gelatin are used as packaging materials for cooked meats. It is also considered as the most successful edible protein. Gelatin coating provides moisture resistance properties and can reduce bioactive ingredients in drinking & food item.
6. Milk Protein: Milk protein is the combination of Casein (80%) and Whey protein (20%). Casein functions as an excellent oxygen barrier and has all the properties that make casein a best option as edible composite packaging natural fiber material. Apart from maintaining the food flavor, the packaging products made from it also help in carrying the nutrients of the food. Casein has pH range between 6 to8 [16].

Fig. 1 Samples made by Sugarcane fiber & Casein

Table 2. Water vapor permeability (WVP) of different natural polymers [17,18].

Film formulation	WVP ($gm^{-1} s^{-1} Pa^{-1}$)
Corn zein	5.35×10^{-10}
Fish skin gelatin	2.59×10^{-10}
Whey protein	7.17×10^{-10}
Wheat glutein	7.00×10^{-10}
Gelatin	1.6×10^{-10}
Amylose	3.8×10^{-10}
Corn starch	2.57×10^{-10}
Methylcellulose	8.70×10^{-10}
Chitosan	4.2×10^{-10}
Casein	7.0×10^{-10}
Soy protein	6.45×10^{-10}
Polyvinylidene chloride	2.2×10^{-10}

Fig. 2 Sample of Composite Material

3. Challenges and Future Directions

Beverage bottles made of edible composite fiber will face a lot of challenges in the future, the biggest challenge being its manufacturing cost. Because I have written this review paper for the Indian market, where we have already seen in the Indian market that everyone avoids buying Cane's cold drinks due to the high cost of Cane's. In developed countries like America, people are using bottles made of edible fibers a lot, but it is a big challenge to reach and popularize it in India. The people of India are quite comfortable with plastic bottles; they need to be made aware of the harm caused by plastic bottles [19]. If we want to popularize the edible bottle among the people in the market, then we have to keep in mind the religious and cultural restrictions of the people. For example, if we are using casein to make bottles, then vegans may not like to buy it [20].

The composites used to make the edible material must comply with the Federal Food, Drug, and Cosmetic Act. During the manufacturing of edible bottles, special care has to be taken to ensure that only healthy ingredients are used. Edible bottles made from animal protein, egg protein or milk protein must be clearly labeled to provide information to consumers with allergies or

religious restriction under the Food Allergen Labeling and Consumers Protection Act of 2004 [21]. Special instruction should be also given regarding edible bottles for their storage and disposing [22].

4. Conclusion

By using edible bottles, the environment around us will be clean, and animals like cows and buffaloes that fall ill after eating plastic bottles while grazing will also get protection. We have also discussed in this review paper that edible fibers have good antimicrobial properties, while the use of plastic bottles are at risk of diseases like cancer [23], from which we come to the conclusion that we should eliminate the use of plastic bottles as soon as possible and the edible fiber bottles are the best replacement for plastic or petroleum based polymers bottles. Edible fiber bottle has the ability to retain the vitamins present in the drink and its flavor as well [24]. Every day, scientist is doing research on new composites so that better edible beverage bottles can be made, as well as research is also going on different types of manufacturing methods so that we can prepare such material whose mechanical properties are much better. For the purpose of stability and safety in the use of these bottles, there is a need for long research on edible packing and edible composite materials, so that these bottles become more and more commercially acceptable between India's bottle manufacturing company and consumer [25].

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