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# Study on Wheat Gluten Biopolymer: a Novel Way to Eradicate Plastic Waste

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**ABSTRACT** *The nonrenewable sources are limited and environmental concerns are increasing regarding the waste from plastics. Hence biodegradable materials made from renewable agricultural resources such as carbohydrates, starch, proteins are attracting much attention for sustainable development and environmental conservation. Plant proteins from wheat show the advantage for usage as films and plastics because of their abundant resources, low cost, good biodegradability and suitable properties like rheological, water sensitivity, sound absorption, thermal behaviour etc. An extensive review of the existing literature reveals that wheat gluten (WG) based bioplastics are non toxics and fully biodegradable, hence in this review various plasticizers and cross-linking agents have been looked upon and their effect on properties studied. Thus, WG based biopolymer poses to be a promising substitute to petroleum based plastics.*

## INTRODUCTION

Average indian consumption of virgin plastic per capita was 3.2 kg in 2000-01 and as per IPF( Indian Plastic Federation) the total consumption of plastic is projected to grow by a factor of six between 2000-2030. The weighted average lifetime of plastic production was calculated as 08 years. 47% of total plastic waste is recycled. Total waste for disposal (excluding recycling) will increase to 10 fold upto year 2030 from current level-1.3 million. The Plastic industry in its nascent stages promised to be a boon to humankind. But with its overuse over the years, it has been a cause of destruction of our ecosystem. [1] It becomes imperative to start searching for substitutes that offer the same quality of services but that are also most importantly biodegradable. The uses of proteins, lipids, cellulose and polysaccharides have thus been extensively studied to obtain biopolymer which would bring the next evolution in plastic industry.

Wheat Gluten (WG), a protein component of wheat, offers such a possibility, mainly because it is water insoluble, elastic in nature, non-toxic, biodegradable. All gluten materials fully degrade after 36 days in aerobic fermentation and within 50 days in farmland soil. Also, wheat is one of the most important staple food grains of human race. India produces about 70 million tones of wheat per year or about 12 per cent of world production. In the year 2012, officials estimate that 6 million tons of India's grain worth $1.5 billion could become inedible as per the USDA Foreign Agricultural Service and Global Agricultural Information network – Annual Grain Report 2012 [2]. This huge amount of inedible wheat can thus be utilized in production of biopolymer. In this review importance has been given to edible wheat and looked at the chances of making a bioplastic with it.

The major components of wheat are starch and protein. The protein component of wheat-Wheat Gluten (WG) is the area of interest here. Conventionally, gluten proteins have been divided into roughly two equal fractions based to their solubility in alcohol–water solutions of gluten (e.g. 60% ethanol): the soluble gliadins and the insoluble glutenins. Hydrated gliadins being less consistent and elastic as compared to glutenins add efficiently to the extensibility and viscosity of the dough system. In contrast, hydrated glutenins are both elastic and cohesive and are responsible for dough elasticity and strength (Herbert Wieser) [3].

## CONVERSION OF WG INTO COMPOSITES

### Extraction of Gluten

Gluten can be readily prepared by gently washing wheat dough under a stream of running water.

When water soluble starch is washed away from wheat flour, the water insoluble protein (WG) remains that retains its cohesiveness on stretching.

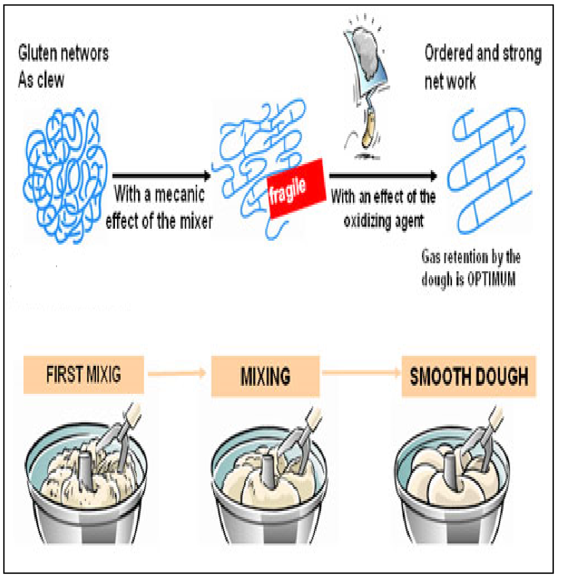


**Figure 1: Steps involved in extraction of gluten**

## SELECTION OF CHEMICALS AND MATERIAL

Many factors are involved in plasticizer selections including

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molecular structures, polarities, required product qualities and properties and costs. Various promising plasticizers that can be utilized in making WG based bioplastic are-

**TABLE: 1**
**VARIOUS PLASTICIZERS[4-14]**

| S.No | Plasticizer Name | Importance |
|---|---|---|
| 1 | Glycerol | Reduces intermolecular forces and the glass transition so as to increase chain mobility of proteins and allow melt processing |
| 2 | Xylan | Helps in the biodegradation of the composite films |
| 3 | Dicarboxylic acids | Forms cohesive and stable blend but its melting point of 128°C is never reached in the mixed blends |
| 4 | Lactic acid | Good hydrogen donor capability |
| 5 | Water | Evaporates during compression molding and therefore does not affect the mechanical properties of the composites and also it provides large melting peak and melting enthalpy |
| 6 | Octanoic acid | Low efficiency due to less hydrogen donating capacity |

Various Crosslinking agents can also be used to improve the properties of the film including:
1) Aldehyde [15]
2) 1-ethyl-3-(3-dimethylaminopropyl) carbodiimide [16]
3) N-hydroxysuccinimide [16]
4) Silica.

Additive like Xylan, Filler like silica, hydro ethyl cellulose, lubricator like Salicyclic acid [17], binder like urea and sodium hydroxide incorporated into gluten in various ratios to form biodegradable composite films.

**Method of Composite Preparation**
WG, glycerol is hand-mixed in a mortar and then mixed on a homogenizer mixer at room temperature. The resultant material is then cold-pressed. Many sets of samples are be prepared by keeping the ratio of gluten to glycerol (plasticizer) as in the range of 0.5 to 0.61. Cross-linking is carried out to improve film properties such as water sensitivity and tensile strength with the help of silica [18]

**Moulding of Composite**
WG films are prepared by vigorously mixing all components in a homogenizer. The film forming solution is then allowed to settle so as to separate the foam formed (30 min). Films are subsequently spread onto a plexi-glass surface using a thin-layer applicator and dried after a smooth application of paraffin oil to avoid early degradation.

**Fig.: 2 Experimental WG films**

**PROPERTIES**
Morphology, moisture absorption, dynamic mechanical properties, tensile properties (tensile strength and elongation at break), and thermal degradation behavior of the plastics produced can be evaluated in relation to the crosslinking type. Some of the main properties are explained below:-

**Rheological**
Partal et all suggests that knowledge of processing effects on the rheological properties of WG based biomaterials is important for the optimization of the productive process and to obtain biomaterials with suitable mechanical properties.[19]

**Fig.3: Stretched Gluten demonstrating its cohesive properties.**

**Water sensitivity and moisture absorption**
In biopolymer-based plastics, the effect of moisture absorption on the thermal and mechanical properties is of great importance to the ultimate usability of the material. The difficulty in solubilising gluten proteins arises mainly from a lack of unionisable groups & the very high molecular weight of the glutenins.Moisture absorption has a great impact on the glass transition temperature of WG proteins. It strongly depends on the relative humidity, decreases very slightly with increasing filler content [19].

**Thermal behavior**
The melting enthalpy of WG without added water is 110 J $g^{-1}$ and that of the WG with water at twice the weight of gluten, as plasticizer was substantially higher at 1.3 kJ $g^{-1}$. Increasing temperature led to a significant decrease in material swelling in high moisture environment .This is attributed to a higher cross-linking degree of protein network for film thermoformed at higher temperature, with a limited mobility and less possibilities of rearrangement in high moisture conditions according to Hélène et.al [18, 20].

There are numerous techniques available for characterization and calculation of different properties of gluten.

**TABLE: 2**
**TECHNIQUES USED FOR MEASUREMENT OF PROPERTIES [21-23]**

| S. No | Techniques | Property measured |
|---|---|---|
| 1 | Rheometric mechanical spectrometer | determines small oscillatory deformation of hydrated glutens, dynamic storage and dynamic loss |
| 2 | Instron universal testing instrument | measures large deformation tensile measurement at ambient of heat-set glutens, breaking stress, breaking strain and tensile modulus |
| 3 | Dynamic shear rheometerw | measure the rheological measurements |
| 4 | Chemiluminescence measurements | observes the impact on chemical changes associated with heating WG |

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| 5 | Solid state NMR spectroscopy | provides information of quantitative composition of phase structure with different mobility in multi component system |
| 6 | Field emission Scanning Electron Microscopy | observes Morphology |
| 7 | Differential Scanning calorimetry and (TGA) Thermogravimetric analysis | calculates thermal properties |
| 8 | X ray and electron Microscopy | detects structure responsible for plastoelastic properties |
| 9 | Electron microscopy (scanning and transmission) techniques | assess particle dispersion and surface interactions |

**SUMMARY**

WG is an inexpensive and abundant co-product derived from renewable resources and is biodegradable. Environmentally friendly thermosetting composites are successfully prepared by conventional blending WG as matrix, glycerol as plasticizer. Utilizing these byproducts for composite applications will add value to the byproducts, improve the income from the crops from which they are derived and benefit farmers economically.

WG can fully biodegrade after 36 days in aerobic fermentation and within 50 days in farmland soil without releasing toxic products. Its protein fraction remains highly degradable, even when it is subjected to severe technological treatments. Its degradation features together with its unique viscoelastic and gas barrier properties make the WG polymer an ideal precursor for the development of new biodegradable polymers.

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