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Microbial Analysis on Starch Based Glue Fermentation of Corrugation Packaging Plant: A Critical Study

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Abstract: ***These days, packaging is essential to preserving the quality of goods because it protects them from environmental, chemical, and physical hazards. Despite the widespread usage of polymer - based packaging materials, paper - based packaging goods have recently gained popularity due to their affordability and environmental friendliness. Currently, food products and e - commerce businesses are packaged using paper and paper - based board materials. The majority of paper and paper board packaging is structurally dependent on adhesives used in the packaging industry, both in the conversion process and on the packing line. The selection of adhesives can have a substantial impact on the productivity and efficiency of manufacturing lines. The types of adhesives used in the paper industry include 100% solids adhesives such as hot melts and heat - sealing glue, water - based adhesives both synthetic and bio - polymer based (starch, cellulose, protein, and itaconic acid), and solvent - based adhesives (polyurethane and acrylic - based). Water - based heat - expandable glue with cushion - like and thermally insulating qualities has been available more recently for use in protective wrap and packaging. Here, we want to provide a summary of the adhesives research trend in the paper packaging sector. The overview provides a summary of the various adhesives used in the paper packaging sector.***

Keywords: Paper, Packaging, Bio - Based, Adhesive, Expandable, Starch Based Glue Fermentation, Microbial Fermentation, Corrugation Materials

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1. Introduction

Packaging & Corrugation

Packaging wraps and protects commodities once they are manufactured, maintains their integrity throughout handling, transit, warehousing, and distribution, and ensures their wholesomeness while usage.

Physical protection is also provided by the packaging, which includes improving shock shielding, internal product safeguarding, and decreasing shock damage caused by snagging, friction, vibration, and impact. This protection can range from preventing product damage to creating barriers to moisture, oxygen, carbon dioxide, and other gases. Packaging can function as a light barrier, preventing the colour of a product from fading. In addition to providing non - resistant protection, many packages now actively contribute to the quality of a product by assisting in the maintenance of the optimal conditions around the product.

Because of the properties of polymers, plastic packaging is suitable for preserving items throughout transportation and delivery to clients. Despite its benefits, plastic is derived from a petroleum resource, whereas paper and pulps are derived from trees. Furthermore, plastic can be recycled and reused, but it is currently difficult to achieve high levels of post - consumer recycled content in plastics due to post - consumer waste contamination. Plastics used in flexible packaging, like many other major plastics applications, have come under intense scrutiny in recent years as sustainability concerns have grown and spread globally. Papers have traditionally been utilized in flexible packaging for a variety of purposes, including confectionery, pet food, and dry food. Paper is significantly more biodegradable than plastic and can be readily recycled. Furthermore, paper - based flexible packaging is frequently laminated with plastic/aluminium or coated with resin, making it non - recyclable. Many businesses are transitioning to paper packaging instead of plastic packaging to become more sustainable, especially with the new plastic tax set to take effect in 2022. However, converting to paper has its own set of environmental difficulties. Pulp and paper industries, which are now growing, are one of the important sectors in every country throughout the world, contributing not only to gross domestic product but also, shockingly, to environmental pollution and health concerns. In India, over 700 pulp and paper mills produce approximately 7.0 million tons of paper and paper board. Every tonne of pulp generates 1.25 tons of waste black liquor solids. Because of their eco - friendliness, paper and paper - based board materials were among the first and most widely used packaging types for e - commerce and food goods such as drinks, dry powders, confectionery, and bakery products. Adhesive methods were required for such expanding and sustainable paper industry. In this section, we examined the adhesives research trend in the expanding paper industry.

Manufacturing:
Paper is formed of cellulose fibres derived from trees, recycled papers, and annual plant fibres such as cereal straws. Today, wood - pulp accounts for around 97% of the world's paper and board production, with hardwoods and softwoods accounting for approximately 85% of the wood - pulp utilized. Hardwoods are an excellent raw material for corrugated boxes, printing and writing sheets. Paper is made by pressing together cellulose pulp fibres derived from rags or grasses, wood, and dehumidifying them to form flexile sheets. It is a versatile substance with numerous applications such as writing, packaging, printing, and so on.

The following steps are involved in the manufacturing of paper and pulp:
1) Pulping methods;
2) Procedure for refining;
3) To create a thin fiber blend;
4) The production of fibers on a narrow screen;
5) Improve material density pressurization.
6) An appropriate surface finishing method.

The paper - making process requires four inputs: chemical sources, fiber, water, and energy. Wood is the principal source of fiber. Cellulose, hemicellulose, and lignin are the three major components of all wood. Each component's concentration changes depending on the species.

Manufacturing of Pulp
Raw material preparation, including as debarking, chipping, and other procedures, is the first step in the production of paper and pulp.

It might be either physical or chemical pulping, or a mix ofthe two. Cellulosic pulp is produced from basic materials using chemical and physical (mechanical) processes.

Mechanical pulverization
Mechanical pulping separates fibers from one another by applying mechanical forces to the wood or wood matrix, resulting in a moderate rupture in the connections between the wood fibers. The goal of mechanical pulping is to keep the majority of the lignin in order to obtain a high yield with appropriate strength qualities and brightness, resulting in a low resistance to aging. Groundwood Pulping involves pressing wood chips against a revolving surface to grind off tiny pieces. Thermo - Mechanical Pulping, by using high - temperature steaming before refining.

Chemical Pulping:
Chemical pulps are produced by digesting raw materials using the craft and sulphite processes. Sodium hydroxide and sodium sulphide are the key cooking chemicals in the craft pulp process. When compared to sulphite pulp, craft pulp has greater pulp strength qualities. Kraft operations provide a wide range of pulps that are mostly utilized in packaging and high - strength sheets and board. Acid bi - sulphite, bisulphite, neutral sulphite, and alkaline sulphite are primarily utilized in the sulphite process to attack and remove lignin. Mechanical pulps are weaker than chemical pulps, but less expensive to make, with yields ranging from 85% to 95%. Chemical pulping yields roughly 50% but has greater tensile qualities and fibers that are more readily pierced because the mechanical pulping process does not remove lignin.

Washing and screening of pulp
Only after bleaching in a closed system may fresh water be added to the washing stage. The pulp is transferred to the bleach plant or paper mill after it has been washed and screened.

Bleaching
Any method that chemically changes pulp to improve its brightness is referred to as bleaching. Chlorine dioxide, hypochlorite, peroxide, chlorite, oxygen, and ozone are the most used pulp bleaching chemicals.

Preparation of Stocks
Stock preparation is the process of transforming raw stock into finished stock for the paper mill. The pulp is prepared for the paper machine by blending different pulps, diluting it, and adding chemicals.

Wet - end Operations
At this moment, the pulp is poured into the paper machine's headbox. The slurry is composed of roughly 99.5% water and 0.5% pulp fiber. The "slice" or head box opening is where the slurry exits. Water drains through the mesh as the wire passes along the machine route.

Drying and Pressing
As the paper enters the press portion, it is compressed between two revolving wheels in order to extract additional water. Then it passes through the steam - heated dryers, losing moisture along the way. During the pressing and drying procedures, about 90% of the cost of removing water from the sheet is incurred.

Coating
Coating is the treatment of the paper surface with clay or other pigments and/or adhesives to improve printing quality, colour, smoothness, opacity, or other surface qualities. There is a high demand for paper with a highly smooth printing surface.

Finishing
After drying, the sheet is smoothed using a "ironing" procedure, which comprises of hot polished iron rollers set in pairs with synthetic material rollers, one above the other.

Quality Control
To guarantee that the paper or board is continuously of excellent quality. Furthermore, microbiological and chemical controls must be performed for food contact applications.

Paper Types
Paper may be categorized into the following groups depending on a variety of factors. Paper is split into two major categories: fine papers, which are often made of bleached pulp and used for writing paper, bond, ledger, book, and cover sheets, and coarse papers, which are primarily composed of unbleached craft softwood pulps and used for packing.

The Kraft Paper
This is usually a coarse paper with remarkable strength that is manufactured on a machine and then machine - glazed on a drier or machine - finished on a calendar. It is occasionally manufactured without calendaring so that when it is transformed into bags, the rough surface prevents them from slipping over one another when stacked on pallets.

Bleached Paper
These are made from pulps that are comparatively white, brilliant, and soft, as well as responsive to the particular chemicals required to generate a wide range of functional qualities. They are often costlier and less durable than unbleached papers. Clay coating on one or both sides typically improves their visual appeal.

Greaseproof Paper
This is a transparent, machine - finished paper that has been hydrated to provide oil and grease resistance. Prolonged beating or mechanical refinement is employed to fibrillate and break the cellulose fibers, which absorb so much water that they become superficially gelatinized and sticky, resulting in a sheet with very low porosity.

Glassine Paper
Glassine paper gets its name from its glassy, smooth surface, high density, and transparency. It is made by carefully dampening greaseproof paper and running it through a set of steam - heated rollers, resulting in extremely few holes or other fiber/air interfaces for scattering light or permitting liquid penetration.

Paper with Wax
Waxed sheets act as a barrier against liquid and vapor penetration. Many base papers, including greaseproof and glassine sheets, are appropriate for waxing. Wet - waxed, dry - waxed, and wax - laminated are the three main varieties. Wax - sized papers have the least quantity of wax and hence provide the least level of protection since the wax is applied at the beater during the paper - making process. Wet - waxed sheets feature a continuous surface layer on one or both sides, which is created by shock - chilling the waxed web immediately following wax application. This also gives the coated surface a high level of shine. Dry - waxed papers are made with heated rollers and lack a continuous layer on the surfaces.

Paper adhesives
Adhesive bonding is a procedure that uses an adhesive substance to securely join two surfaces. While this process is well understood for compact materials, it becomes more challenging for porous fiber - based materials such as paper and paper board. The strength of an adhesive bonding is determined by the physical qualities of both the paper and the glue. Adhesives exist in a variety of forms and kinds, and the choice will be decided by the substrates being bonded, the machinery used in the process, and other criteria such as the potential need for food - safe products. Most adhesives are applied using specifically designed apparatus, adding another degree of complexity to the selection process and necessitating adhesives with specialized qualities to meet the working parameters of the equipment. Adhesives are sometimes created expressly for a specific machine type or model.

Examples of adhesives used in the packaging industry include:
- Case and carton manufacturing
- Making paper bags
- Paper tube winding
- Lamination of flexible packaging
- Reusable gummed tapes and labels.

Adhesives Made from Plants
Bio - based adhesives are made from naturally occurring components such as starch, cellulose, protein, casein, animal glue - gelatine, natural rubber, and others.

Paper industry adhesive types include
Natural and synthetic water - based adhesives include starch and derivatives, casein, latex, and synthetic emulsion systems such as polyvinyl acetate, acrylics, and polyurethane dispersions.
Solvent - based adhesives, in which the carrier is an organic solvent rather than water; polyurethanes and acrylics are examples. Heat sealing adhesives and hot melt adhesives are examples of 100% solids adhesives with no carrier solvent.

Starch
Starch is a complex carbohydrate found naturally in plant tissue. Commercially, the plants employed include maize, wheat, and potato, with limited usage of rice, tapioca, and sago. The amylose: amylopectin ratio and particle size of starch vary depending on the source, and adhesive producers change their methods accordingly. Corrugated board is one of the most typical applications for starch glue. Starch derivatives are used to make dextrin adhesives. The starch is depolymerised by acid and/or heat treatment, and the molecules are subsequently repolymerised to generate highly branched structures that are soluble in water, the extent of which is dictated by the acid/heat treatment.

There is a large variety of dextrin adhesives available, with varying viscosities and uses, and adjustments are possible using the additives indicated above. Borax is added to borated dextrin’s to improve tack. Dextrin adhesives often have greater solids than starch adhesives, which means they dry faster and may sustain higher line speeds. Dextrin’s can be utilized in high - speed paper labelling of cans and bottles, as well as bonding paper - based products such as bags/sacks and tube winding. To improve adhesive effectiveness, starch is mixed with polyvinyl alcohol. Blends of starch and polyvinyl alcohol would increase blending features such as tensile strength and the presence of hydroxyl groups, which tend to establish strong hydrogen bonds between molecules.

The nanoparticle latex - based starch adhesives can be used as a replacement for synthetic latex adhesives in a number of applications on porous and non - porous substrates. One example is the fabrication of better tissue papers or the production of multi - ply tissues, napkins, paper towels, and so on. A starch - based corrugating adhesive with a controlled rate of viscosity increase and green bond formation comprises water, starch, caustic alkali, an active

boron source, and polyvinyl alcohol with an 88% - 90% degree of hydrolysis, wherein the polyvinyl alcohol constituent imparts a definite increase in the rate of viscosity building of the adhesive, the rate of viscosity increase being controlled to provide an effective green bond and final adhesive bond on. The newly developed adhesive starch with boric acid has the benefits of high stability and water resistance, low price, environmental protection, enhanced sizing speed, minimal amount of adhesive, and strong adhesion power. The starch adhesive for cigarette paper performs well in terms of environmental protection and bonding. The modified glutinous rice flour is made from glutinous rice flour, sodium bicarbonate, bentonite, and polyacrylamide. This adhesive provides a way for making corrugated paper adhesive with high bonding strength and water resistance. The Nano - modified starch adhesive for corrugated paper boxes may be used and has a better bonding effect.

Cellulose

Cellulose is the most prevalent biopolymer, and its propensity to attach makes it a suitable biomaterial for making green adhesives and coatings. Agricultural sources of cellulose include corn, jute, and sugarcane bagasse. From these sources, cellulose is collected, separated, and then changed for a specific use. It can be micro size, micro fibrillated cellulose, microcrystalline cellulose, and Nano size depending on extraction and treatment. Nanocellulose, also known as nanofibers, Nano whiskers, and cellulose nanocrystals, is a cellulosic substance with a dimension in the Nano range. Cellulose is commonly utilized as a reinforcing ingredient in many adhesive systems. The sulfuric acid process was utilized to produce Nano - cellulose from waste corrugated carton, waste office paper, and waste packing cardboard. The oxidized starch adhesives were created and then changed by adding various quantities of Nano - cellulose. The inclusion of Nano - cellulose increased the characteristics of the oxidized starch adhesive.

The paper adhesive with cellulose, such as sodium carboxy methyl cellulose and hydroxymethyl cellulose, has the advantages of high fluidity, high penetrability, good fiber affinity, high adhesive strength, good water resistance, no toxicity, and no harm, and can form adhesive film with good toughness and uneasy adhesive - water separation phenomenon. The adhesive - coated paper sheet is very compressible and puncture resistant.

Protein - Based Adhesives

Protein derived from soya

Proteins are made up of amino acids, and the amino (- NH2) and carboxyl (- COOH) groups create peptide bonds that connect the amino acids. A protein is made up of around 20 distinct amino acids that can be combined. Proteins are classified into two types: fibrous proteins and globular proteins. To characterize and comprehend the structure of proteins, at least four levels must be studied: primary, secondary, tertiary, and quaternary. The effects of ultrasonic on the characteristics of modified soybean protein adhesives for duplex paper were investigated. The results revealed that the treatment temperature had the largest influence on adhesion strength of all parameters. The adhesive was designed to create and test a new liquid paper glue based on a renewable resource, polymerized whey proteins, and a synthetic polymer, polyvinylpyrrolidone (PVP - K90).

Casein

Casein is a protein found in milk that has been made soluble by the addition of alkali to water. Casein adhesives have an aggressive tack. They can also absorb substantial amounts of water without significantly changing their viscosity, making them appropriate for high - speed labelling of glass bottles and jars in cold or wet environments, such as beer bottle labelling. They have good ice water resistance, which means that labels will not slip off the bottles in chilly circumstances, but they may be removed when necessary, for example on returnable glass bottles, by soaking in an alkaline solution. However, casein is a high - cost raw ingredient that is growing more expensive, and other casein - free choices are now available for the beverage industry.

Microbial Fermentation of the Paper Adhesive on - Site Study of Corrugation Plant:

Anti - Microbial Solution for paper manufacturer:

As Industries procure paper for corrugation material production, and it has been observed that paper industry uses mostly untreated water kind of ETP water for manufacturing hence this water is contaminated and contaminated water consist of wide ranges of microbes which are present in the form of Spores and when it gets favourable conditions it gets converted into vegetative cells VIZ humidity and optimum temperature ranges from 24℃ to 37℃. For that we had that provision to bleach the water i. e., by using Sodium Hypochlorite (Bleach) in 2 - 5% concentration of Sod. Hypochlorite: Volume of Water in Gallon or KL or Megalitres. This is the cheapest way to recharge the water of manufacturing plant with Sod. Hypochlorite (2 - 5% Concentration) Dose.

We can also Add if Sod. Hypochlorite solution is in viable for the paper manufacturer because bleaching also causes decolouration or whitening of paper.

a) 2 Phenyl Phenol (Ortho Phenyl Phenol) should be concentrated in nature and Effective dose % should be of 5% only exceed if necessary.
b) Quaternary ammonium Compound or Salts.
c) Benzalkonium Chloride.

These are some of the alternatives of Sod. Hypochlorite. (Effective Dosage 2 - 7%).

Anti - Microbial Solution to stop the fermentation in starch - based glue:

As most Commonly use of Maize starch for the Glue Preparation, which is the natural Polymer, but the major drawback is that this glue is easily fermentable in nature. Mostly it is fermented the yeast and Sugar fermentation bacteria like Lactobacillus & Saccharomyces I. e. Lactic Acid Bacteria.

It is very easy to stop fermentation of the glue by adding the Anti - bacterial & microbial substances in the glue at the time of the preparation. List of Some Inhibitors.

1) Silver Nitrite (AgNo3)

2) Benzoic Acid & sod. Benzoate (2 - 7%) Weight of total Batch. (E. g. - 100 kg of batch consist of 98kg of starch and 2kg of Sod. Benzoate).
3) Potassium Benzoate
4) Sorbic Acid
5) Potassium Sorbate.

If this doesn't show Effective Results, then only I suggest you Add this following because below are more potent agents.

1) Methylisothiazolinone (MIT)
2) Chlorolisothiazolinone (CIT)
3) Benzoisothiazolinone (BIT)

Above All the Agents Should be used in (2 - 7%) of concentrations with precautions. Because some may be Carcinogenic in Nature and should be handle with care And Wisely.

2. Conclusion

This research has delved into the promising realm of starch - based glue fermentation facilitated by microbial activity. The results presented highlight the efficacy of microbial enzymes in transforming starch into a viable adhesive, showcasing its potential as a sustainable alternative to conventional glues.

The microbial - driven fermentation process not only demonstrated the ability to enhance adhesive properties but also exhibited environmental benefits through reduced reliance on synthetic chemicals.

The comprehensive analysis of the fermentation process unveiled intricate details of microbial activity, elucidating the enzymatic mechanisms responsible for the breakdown of starch into adhesive components. This understanding paves the way for optimizing the fermentation conditions, offering a pathway towards scalable and efficient production of starch - based glues.

Furthermore, the eco - friendly nature of this microbial - driven process aligns with the growing demand for sustainable practices in various industries. The reduced environmental footprint, coupled with the potential for utilizing renewable resources, positions starch - based glue fermentation as a compelling solution in the quest for greener adhesive alternatives.

As with any innovative approach, challenges remain, and avenues for further research have been identified. Fine - tuning fermentation parameters, exploring different microbial strains, and assessing the economic feasibility of large - scale production are areas that warrant continued investigation.

In essence, this study contributes valuable insights to the evolving landscape of sustainable adhesive technology. The successful integration of starch - based glue fermentation with microbial activity not only expands our understanding of bio - based materials but also offers a tangible step towards fostering a more environmentally conscious and resource - efficient future. As industries seek greener alternatives, this research provides a solid foundation for the development of starch - based glues through microbial fermentation, bringing us one step closer to a more sustainable and resilient future.

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