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UTILIZATION OF SODIUM ALGINATE AS A FIBER BINDING MEDIA IN THE TEXTILE WASTE RECYCLING PROCESS

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ABSTRACT

The textile industry is a crucial sector in human life, but it is also the largest contributor to global waste. Textile waste that is difficult to decompose causes serious environmental problems, ranging from water pollution to increased greenhouse gas emissions. One potential solution is a recycling method using an environmentally friendly biomaterial approach. This study discusses the use of sodium alginate, extracted from brown algae, as a binding medium for textile fibers in the textile waste recycling process using the crosslinking method with calcium chloride ($CaCl_2$). Water-soluble sodium alginate reacts with calcium ions to form a strong and elastic gel. Through this process, textile waste such as fabric and yarn is crushed into staple fibers and then re-bonded using a sodium alginate and calcium chloride solution. This crosslinking process strengthens the bonds between the fibers, creating a new material in the form of alginate-based yarn that can be reused in the development of sustainable textiles. The results show that the combination of sodium alginate and calcium chloride can form a strong bond that is waterproof, flexible, and environmentally friendly. Thus, this method provides an innovative alternative in textile waste management while supporting the principles of a circular economy in the fashion industry.

Key Words: Textile Waste, Sodium Alginate, Recycling, Biomaterial

INTRODUCTION

The textile industry is a vital component of human life. Many human needs and requirements are produced by the textile industry, from the most basic, such as clothing, to contemporary trends and even interior decoration. All products produced in this industry are made from fibers, which are then processed using various methods to produce the desired textile products. These textile products range from basic materials like fabric and yarn to fashion items. This increasing scale of textile production has led to a significant increase in waste production. Globally, 75% of textile waste is disposed of in landfills, while 25% is recycled or reused (Juanga-Labayen et al., 2022).

The ever-evolving industry generates a variety of waste types. Most textile waste is highly biodegradable due to the use of chemicals as the raw materials for its products. This difficulty in decomposing waste creates multiple problems for human life and the environment. Not only will waste continue to accumulate, but greenhouse gases also pollute the Earth's atmosphere. The textile industry, particularly the fashion industry, contributes 8 to 10% of global carbon emissions. This is due to uncontrolled production activities and unmanaged textile waste. This figure is expected to increase to 50% by 2030 without proper production controls and waste management.

High consumer demand for textile products, especially fashion, forces the industry to continually meet market demand. It's not uncommon for products to compromise quality in favor of achieving quantity quickly. Supported by highly dynamic trends, the market easily shifts from one trend to another. To meet such dynamic market needs, many industries have shifted to using polyester to reduce production costs and increase unit yields. Before 2002, demand for cotton fiber dominated the global textile industry and significantly outpaced demand for polyester, the most widely used fiber in the industry, accounting for 52.5% of global fiber production in 2019, followed by cotton fiber at 23.2%.

The textile industry's raw materials, dominated by synthetic fibers, have led to a surge in environmental problems from the production process through to consumption. These environmental problems are caused by various forms of waste, such as dye waste that pollutes water and production waste that ends up in landfills. According to Agrawal et al. (2013), textile waste can be classified into pre-consumer and post-consumer waste. Pre-consumer waste is generated from materials and production activities used to produce various textile products such as fashion, interiors, etc. Meanwhile, post-consumer waste is generated when consumers no longer use a textile product and choose to discard it. It is recorded that textile production activities have a pollution percentage of 36% for the dyeing and finishing stages. Furthermore, approximately 92 million tons of total waste in the textile industry are produced annually.

The textile industry, particularly fashion, ranks third among the most polluting industries globally. The textile production process, which uses vast amounts of water, energy, and resources, has a negative impact on humans and the environment. Addressing the problem of textile waste requires solutions that do not increase the pollution burden and aim to minimize waste circulation. Algae is a material that is increasingly being developed for various functions and sectors. Technological developments have led to algae becoming a research object for biomaterials. Biomaterials in the textile industry are also starting to emerge as an answer to environmental problems. Algae hold great promise due to their well-known ability to absorb carbon, particularly carbon dioxide (CO_2), as a nutrient source for growth through photosynthesis.

One of the most well-known algae extraction products is sodium alginate. Specifically, the majority of sodium alginate comes from brown algae extraction. Sodium alginate is a polysaccharide with a low toxicity level, so the process does not produce emissions, this is in line with the goal of addressing the problem of textile waste, which causes significant carbon emissions. Sodium alginate is generally easily found in white powder form. When exposed to water, sodium alginate will easily dissolve, forming a water-based gel that does not require special heating or cooling. Its adhesive properties are often used as a binder or binding agent for other materials using the crosslinking method. The crosslinking method aims to exchange the ions contained in sodium alginate with ions contained in the crosslinker. The type of crosslinker used to support maximum environmentally friendly methods is to avoid synthetic crosslinkers. Non-synthetic crosslinkers can be found in calcium chloride ($CaCl_2$). Most calcium chloride comes from limestone or chalk that is processed through saltwater purification.

The synergy between sodium alginate and calcium chloride through crosslinking produces a strong gel that can be applied in various binding functions. The interaction of the polymer solution and the calcium chloride solution results in the exchange of positive ions from calcium and negative ions from alginate through diffusion or exchange of ion pairs between the two. The result of this crosslinking not only produces a strong gel that can be used as a binding agent but also experiences improved mechanical properties. The improvement in mechanical properties can be seen in the change from a gel that is easily soluble in water to a gel that is denser and insoluble in water and elastic at the same time. This occurs because the crosslinking process forms a wall structure on the surface of the alginate, which is the main structure in achieving the final result of a water-resistant gel.

In this case, sodium alginate can be used as an environmentally friendly textile fiber binding medium. Staple-shaped textile fibers are the right type to be bound by alginate through a crosslinking process with calcium chloride. With this method, textile waste can be the primary target for binding, focusing on textile waste in the form of fabric, yarn, and fiber. In the process of obtaining staple fibers, textile waste, especially in the form of fabric and yarn, needs to go through a crushing process to form short, fine fibers. The type of textile waste that can be used does not have specific qualifications, so the scope of textile waste recycling can be comprehensive. This method can be a promising recycling step to address waste in the textile industry. This recycling step can produce a new basic fashion material in the form of alginate yarn.

METHODOLOGY

This topic uses Graham Wallas' Creative Process design approach, one method often used in understanding and managing innovation and design processes. In civilized adults, it is very difficult to observe mental behavior other than acquired habits; but if we make a rough distinction between nature and acquisition, we will find that the main 'natural' process that the art of thinking tries to change is the 'association of ideas', which was observed by Aristotle and Hobbes by studying these properties. (Graham Wallas, 1926:59). Graham Wallas describes four stages in the creative process. These four stages serve as a guide to understanding the formation of creative ideas. This approach consists of four main stages: Preparation, Incubation, Illumination, and Verification.

Preparation

It begins with the preparation stage, the initial step in the creative process, focusing on understanding the challenges faced. Activities undertaken in this stage include gathering data, information, and facts related to the topic. Using the collected data, it's then necessary to research the problem and open your mind to possible solutions.

Incubation

The second stage is incubation, which requires resting the active mind and beginning to subconsciously process the problem. This stage involves allowing time for unpressured reflection in order to find a solution. During this stage, engaging in activities other than focused research is perfectly acceptable. Reflective activities, such as walking and meditation, allow the subconscious mind to work and acquire information in unexpected ways.

Illumination

The third stage is illumination, a stage known as the moment of enlightenment. This is when a solution or idea emerges, like suddenly having a clear insight into a solution to a problem. The solution or idea that emerges often feels right or is intuitive. In this stage, the conscious and subconscious minds collaborate to arrive at a solution or idea.

Verification

The final stage is verification, known as the process of testing and validating the idea or solution discovered. This involves further developing the idea so that it can be implemented. Testing the solution ensures its effectiveness and the challenges it faces in implementing it in real-world situations.

RESULT AND DISCUSSION

Preparation

At this stage, activities include problem identification and data collection for environmentally friendly designs using sodium alginate. This identification is carried out by observing global textile problems and seeking innovations in textile waste management. After identifying the main problem, data collection is necessary. Data collection for this design was carried out through literature studies and visual studies of sodium alginate as a natural material and its application in the textile industry. Observations were also made by looking at references from textile designers or artists who have used sodium alginate as a material in experimental techniques.

Incubation

After the preparatory phase of data collection, the next step was to consider the potential application of sodium alginate as a binding medium for textile fibers using the crosslinking method. At this stage, many ideas developed beyond logical analysis. Random references on Pinterest, related journals, and personal freehand sketches, even simply relaxing, allowed design ideas to emerge subconsciously.

Illumination

The emergence of this solution was marked by the idea of a product form derived from binding textile fibers: yarn. This yarn is the result of a *crosslinking method* using sodium alginate and calcium chloride as a binder for the textile fibers. The resulting *wet spinning crosslinker* is a long strand called alginate yarn.

Textile Waste → Fiber binding using sodium alginate → Alginate yarn

Picture 1 Wet Spinning Crosslinker

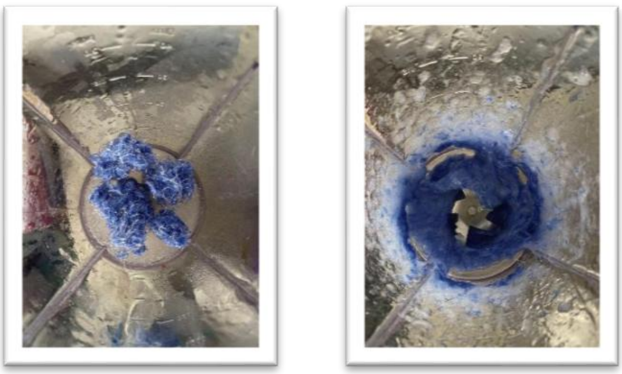
Verification

Verification is carried out by conducting experiments on fiber binding using sodium alginate, testing the application of textile techniques to alginate yarn, and assessing the success of this idea. Through a lengthy experimental process, the effectiveness of sodium alginate in the textile fiber binding process and the durability of the alginate yarn will be revealed. At this stage, there will be many failures and successes, and the experimental results need to be evaluated from a technical, aesthetic, and functional perspective.

The first test was conducted on the textile shredding process, comparing the dry and wet methods. The dry method was performed using *a blender* without water, while the wet method was also performed using *a blender* with added water. The test results showed that the dry method was more effective, producing more textile fibers than the wet method.

Picture 2 Test Results The Dry And Wet Methods

The next test was on the dosage and method of making the alginate solution and textile fiber. An experiment was conducted to make an alginate solution with 10 grams of sodium alginate, 20 grams of glycerin, and 500 ml of water. The correct dosage ratio for making the alginate solution was found to be 1:2:50. The solution was blended *and* then 3 grams of textile fiber was added and blended again.



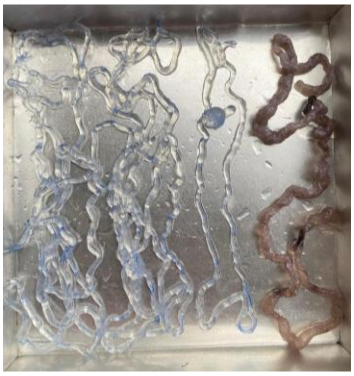
Picture 3 Test Results The Alginate Solution And Textile Fiber

Crosslinking process involves spraying a polymer solution (sodium alginate, glycerin, water, and textile fibers) through a *piping bag* into a coagulation tank containing a 1:10 solution of calcium chloride and water. The contents of the coagulation tank act as *a* crosslinker, solidifying the polymer. The pressure applied when spraying the polymer solution must be stable to create long strands of alginate yarn.

Picture 4 Test Results The Drying Method Of Alginate

In the final stage of the alginate yarn manufacturing process, a trial was conducted on the drying method of alginate yarn that had come out of the coagulation bath. Drying aims to shrink the yarn and reduce the water content to produce alginate yarn products that meet the qualifications of textile properties. Three methods were tested: drying using an oven, drying by drying under direct sunlight, and finally drying by drying in a shaded area. The most efficient method obtained and producing the best yarn quality was drying in a shaded area at an effective air temperature ranging from 27°C-32°C. The shrinkage that occurs in alginate yarn ranges from 50%-75% of its initial size.

Table 1 The Test Results

No.	Method	Results
1.	Drying using an oven.	  - The drying results are uneven. - The thread breaks easily because some parts are too dry. - The quantity of yarn each time drying is not too much due to the limited size of the oven. - The thread is a bit curly. - Save time.
2.	Drying by drying under the sun.	 - The result is too dry. - Less flexible. - The thread surface feels too rough. - The quantity of yarn is greater due to

No.	Method	Results
		adequate drying space. - The thread is straighter.
3.	Drying by drying in a shady place at an effective air temperature of 27°C-32°C.	 - The result is not too dry. - The thread is quite flexible. - The thread surface feels smoother. - The quantity of yarn is greater due to adequate drying space. - The thread is straighter.

To assess the suitability of alginate yarn as a recycled textile product, a trial application of the technique was necessary. The textile technique chosen was crochet. *Crochet was chosen* as the testing method because *it can be applied to various types of yarn. Several types of crochet* stitches were tested on the alginate yarn, as follows:

Table 2 Types Of Crochet Stitches

No.	Types of Crochet	Visual
1.	*Chain*	

No.	Types of Crochet	Visual
2.	*Magic circle*	
3.	*Single crochet*	
4.	*Half Double Crochet*	
5.	*Double crochet*	
6.	*Triple crochet*	

No.	Types of Crochet	Visual
7.	*Wave stitch* (a combination of *chain, single crochet, half double crochet, double crochet,* and *triple crochet*).	
8.	*Freeform crochet* (a combination of all types of crochet)	

CONCLUSION

Based on the discussion that has been conducted regarding the use of sodium alginate as a fiber binding medium in the textile waste recycling process, it can be concluded that sodium alginate has great potential as an environmentally friendly alternative material for re-binding recycled textile fibers. The natural properties of sodium alginate which are easily soluble in water and able to form a gel or film layer make it effective in uniting fiber particles without the need for hazardous synthetic chemicals. To support the formation of a strong gel or layer, *a crosslinker* in the form of calcium chloride is needed as a stable gel structure former. Thus, the *crosslinking method* using calcium chloride in sodium alginate can be concluded as an effective, ecological, and applicable approach in re-binding recycled textile fibers, as well as providing a real contribution to the development of sustainable materials in the textile and design industry.

In its application process, sodium alginate is able to produce a new material texture that is strong enough for the needs of yarn products. The results of the trial show that combining fibers with sodium alginate can form a material with flexibility and strength that can be adjusted based on the concentration and processing techniques used. In addition, the use of sodium alginate in the context of textile recycling also shows a sustainable approach, because it not only reduces textile waste, but also minimizes the use of hazardous chemicals and provides opportunities for innovation in the textile sector. Thus, the use of sodium alginate as a fiber binding medium can be an effective, sustainable, and innovative alternative solution in addressing the challenges of the textile industry that is oriented towards a circular and environmentally friendly economy.

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