Journal of Advanced Zoology

ISSN: 0253-7214

*Volume **44** Issue **S-6 Year 2023** Page **1582**:**1590***

Use of Agro-Industrial Waste from The Cereal Sector to Obtain Cellulose

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Article History

Received: 06 June 2023
Revised: 05 Sept 2023
Accepted: 06 Dec 2023

Abstract

The agro-industrial grain industry generates a large amount of waste, which is often discarded, leading to environmental problems and the potential loss of valuable resources. However, in recent years an innovative approach has emerged that aims to use this waste to obtain cellulose, a compound with several industrial applications. The process of extracting cellulose from agro-industrial by-products of the food industry involves stages such as harvesting and milling, followed by a chemical and/or enzymatic treatment to obtain pure cellulose. Dependence on primary sources of pulp such as wood is reduced, thus contributing to the conservation of forests and natural ecosystems. In addition, the use of agro-industrial waste for pulp production reduces the amount of waste burned or poorly discarded, thus minimizing the environmental impacts associated with its disposal. Inadequate, in addition to the environmental benefits, the use of agro-industrial waste to obtain cellulose can also generate economic opportunities for many families who can use this medium to grow economically..

Keywords: *Rice husks, Sustainability, Cellulose, Agribusiness, Environmental*

1. Introduction

Agro-industrial waste is a major environmental problem worldwide, as its improper disposal can have a negative impact on the environment and human health. (Yuri, 2018)

However, this waste can also be a valuable source of useful materials and products. In particular, agro-industrial waste from the cereal sector can be used to obtain cellulose. Cellulose is a versatile material that is used in a wide variety of applications, from the production of paper and cardboard to the manufacture of textiles and pharmaceuticals. (Casas, 2021)

Agro-industrial waste from the cereal sector includes leaves, stems, straws and other materials that are generated during the production and processing of cereals such as rice, maize and wheat. This waste contains a significant amount of cellulose, which can be extracted and purified for use in various applications (Callejas, 2016)

The extraction of cellulose from agro-industrial waste from the cereal sector can be a sustainable and cost-effective alternative to the production of cellulose from conventional sources such as wood. Cellulose extraction can be done by different methods, such as acid hydrolysis, enzymatic hydrolysis, and ozone oxidation. These methods make it possible to obtain high purity and quality cellulose, which can be used in a wide variety of applications (Peñaranda, Montenegro, & Giraldo, 2017)

The use of agro-industrial waste from the cereal sector to obtain pulp is a sustainable and cost-effective alternative to pulp production. The extraction of cellulose from agro-industrial waste from the cereal sector can have a positive impact on the environment and can provide a valuable source of useful materials and products.(Cury, 2017)

Poor waste management

One of the main problems is the mismanagement of cereal residues in the industry. This refers to the way in which the waste generated during the production and processing processes of cereals is managed and disposed of. If not properly managed, this waste can have a negative impact on the environment and human health.(Organización de las Naciones Unidas, 2018)

Environmental impact

Improper production and management of cereal residues in industry also have a negative environmental impact. The cereal production process can lead to greenhouse gas emissions, excessive water consumption, and soil and water pollution. Poor waste management can exacerbate these problems, contributing to climate change, water scarcity and biodiversity loss.(Organización munidal de la Salud, 2022)

For them, some companies are implementing circular economy practices, which seek to reduce, reuse and recycle cereal waste. This can include using by-products as ingredients for other products, producing biogas from waste, or feeding animal waste to waste.

In conclusion, the problem of cereal residues in the industry is an issue that requires the attention and action of multiple actors. Improved waste management, reduced food loss, and sustainable practices promoted in the grain industry are needed to address this challenge effectively.(Rodriguez A. , 2018).

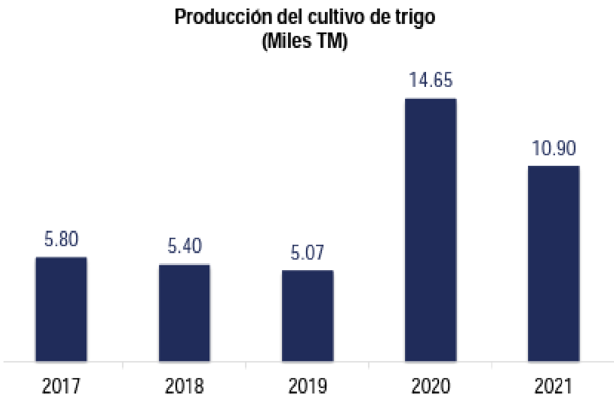
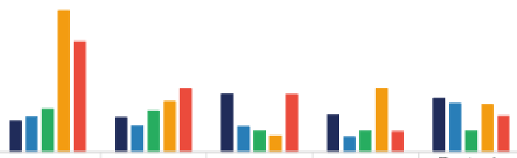


Figure 1: Cereal production in Ecuador

For the year 2021, the harvested area of wheat in Ecuador was 6,038 hectares, covering a production of 10,898.(Coorporación Financiera Nacional, 2017)



	Carchi	Bolívar	Pichincha	Chimborazo	Resto de Provincias
2017	647	721	1,220	781	1,120
2018	739	554	533	304	1,018
2019	902	859	443	440	441
2020	2,967	1,058	340	1,336	997
2021	2,325	1,332	1,211	418	752

Figure 2: Harvested area by province

The province of Carchi accounted for 55% of the national production of this sector, followed by Bolívar (18%) and Pichincha (17%).(Coorporación Financiera Nacional, 2017)

From these data it can be understood that there is waste of about 6% to 12% of the cereal harvest as well as in the processing of products. Keep in mind that these percentages can vary depending on a variety of factors, such as crop management practices, storage, and grain processing. Importantly, reducing food waste, including grains, is crucial to ensuring food safety and minimizing the environmental impact of food production.

Agribusiness has the capacity to promote economic, social and environmental development, as long as it maintains the balance between the activity carried out and the protection of the environment in each of its processes, from the handling of raw materials to the distribution and final disposal of the by-products or waste generated. (Soto, Michelle, 2018)

When it comes to reusing cereal waste, we obtain several benefits, such as:

Waste reduction: By reusing the amount of cereal waste, it is avoided its accumulation in landfills or its improper disposal, thus reducing the waste generated and its environmental impact.(ECODES, 2022)

Nutrient recycling: Grain waste can contain valuable nutrients, such as carbohydrates, protein, and fiber. By reusing this waste, these nutrients can be recovered and used in the production of food and fertilizers, thus contributing to a more efficient use of resources and the circular economy.

Power Generation: Cereal waste can also be used for the production of biogas or biofuels through anaerobic fermentation processes. This contributes to the diversification of energy sources and the reduction of dependence on fossil fuels.(Berguer, 2015)

Economic value: Reusing grain waste can create economic opportunities by creating new products or raw materials. For example, waste from cereal production can be used in the manufacture of foodstuffs or in the manufacture of paper, cardboard or building materials.

Characterization of agro-industrial waste

Waste Agro-industrial products are mainly solid and organic, rich in cellulose polymers and hemicellulose (75% to 80%). A small amount of agro-industrial waste is used for animal feed, energy obtained from combustion processes and organic fertilizers, etc. But most of them burn in the open field, causing non-biological environmental pollution.(Fernandez A. , 2014)

Cellulose extraction technology from agro-industrial waste that separates hemicellulose and lignin, and the energy process itself that separates cellulose fibers by dissolving lignin by fermentation, based on mixtures of NaOH and Na2S, all of the above, based on agro-industrial waste Access to cellulose research, this work aims to contribute to the reader and strengthen the knowledge of cellulose extraction methods. (Ramón & Ramón , 2012)

2. Materials And Methods

Methods of obtaining cellul

Obtaining cellulose can be done through several methods, where some of the most common methods to obtain cellulose are: Chemical Methods: Cellulose can be extracted from wood or other plant materials using chemical treatments. One of the most commonly used processes is the Kraft process, where a solution of sodium hydroxide and sodium sulfide is used to separate cellulose fibers from other components of the wood. Other chemical methods include sulfite pulping and oxygen pulping.(Sanz A. , 2020)

Mechanical Methods: In this method, cellulose is obtained by crushing and grinding plant material, separating the fibers from other parts of the pulp mill. This process is mainly used in the manufacture of recycled paper.(Salgado, Gracia, & Lopez, 2017)

Enzymatic methods: Enzymes are used to break down plant materials and separate cellulose fibers. This method can be gentler and more environmentally friendly compared to traditional chemical methods.(Gutierrez & Moreno, 2015)

It is worth mentioning that the choice of method for obtaining cellulose may depend on the type of material used and the specific applications for which it is needed. In addition, research is underway to develop more efficient and sustainable methods for obtaining cellulose from various natural resources.

Techniques for pulp extraction

To extract cellulose from a cereal, several methods can be applied. One of the most common methods is the alkaline pulping process. A step-by-step summary of the process is provided below:

Preparation of the cereal residue: The cereal residue is cleaned and any impurities removed before the cellulose extraction process begins.

Crushing: Grinding or crushing is carried out to break down the cell structures and facilitate the extraction of cellulose.

Alkaline extraction: After grinding, it is immersed in an alkaline solution, usually of sodium hydroxide (caustic soda) or potassium hydroxide. The alkaline solution helps separate cellulose from other components of the cereal.

Cooking: Once crushed, it is boiled in the alkaline solution for a set period of time to break down the fibers and release the cellulose.

Filtration and washing: After cooking, the solution is filtered to separate the cellulose fibers from the residual liquid. The fibers are washed to remove any impurities or residues from the alkaline solution.

Bleaching: In some cases, cellulose fibers undergo a bleaching process to remove any additional coloration or impurities.

Cellulose was obtained by means of the procedure reported in the literature, the process was carried out in triplicate for each of the wastes.

The process of obtaining cellulose requires several processes, first, a firing with NaOH in order to dissolve and degrade the lignin and hemicellulose of this plant material, the obtaining of cellulose was optimized by varying the time, temperature and concentration of sodium hydroxide.

This study showed that it is possible to obtain cellulose from agro-industrial waste in the cereal sector, reaching 50% of pre-treated fiber yield, which through chemical treatment of acid hydrolysis and bleaching obtains a yield of 34% of final cellulose.

Agro-industrial uses of the production of cellulose from waste from the cereal sector

Cellulose has a variety of uses due to its unique properties. Here are some common uses for cellulose:

Paper industry: Cellulose is widely used in the manufacture of paper and cardboard. The cellulose fiber is made into pulp, which is then processed and used to produce different types of paper, from writing paper to packaging paper.(Ministerio de agricultura_Argentina, 2022)

Textile industry: Cellulose is used in the production of textile fibers, such as rayon and lyocell. These fibers are soft, absorbent and comfortable to wear. It is also used in the manufacture of nonwoven fabrics for products such as diapers and feminine hygiene products.(Parra, 2022)

Food industry: Cellulose is used as a food additive to improve texture, stabilize emulsions, and increase viscosity. It is also used as a thickening agent in products such as sauces, ice cream, and processed foods.(Moncel, 2020)

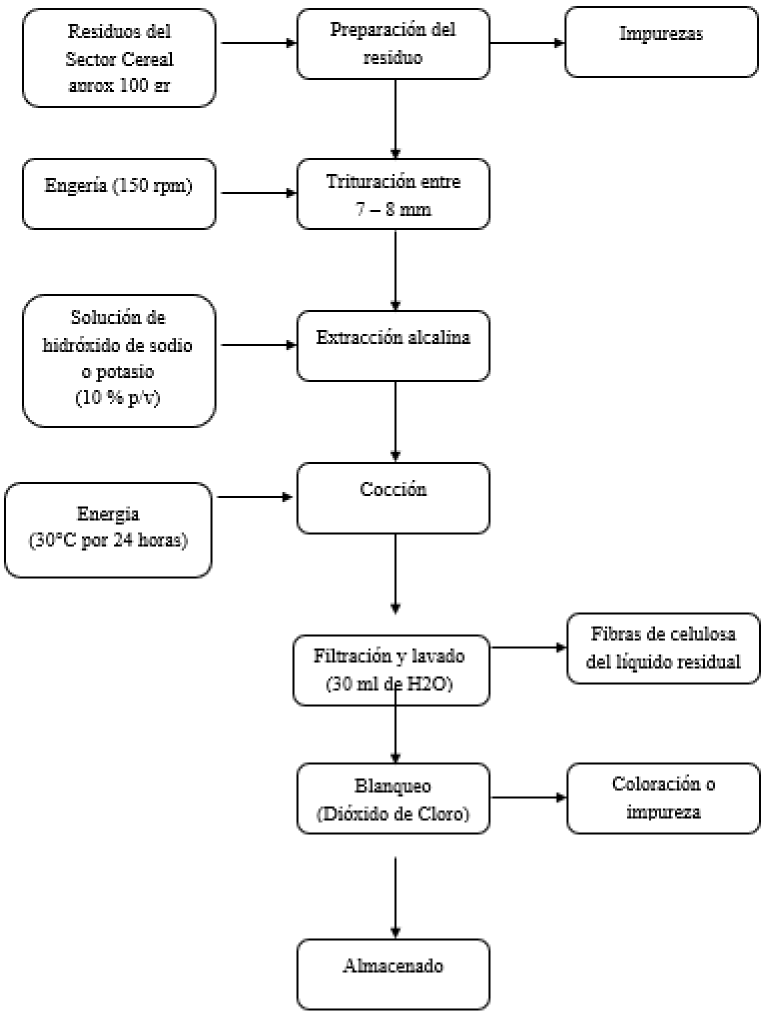
Pharmacist: Cellulose is used in the manufacture of pharmaceutical tablets and capsules as a bulking agent and adhesive. It is also used in the production of tablet coatings and in the manufacture of sustained-release medicines.(Universidad de Antioquia, 2023)

Cosmetic Industry: Cellulose is used in the cosmetic industry to stabilize and thicken products such as creams, lotions, and makeup. It is also used in hair care products, such as shampoos and conditioners.(Valera, 2020)

Cellulosic matter is also one of the environmental alternatives when it comes from the use of agro-industrial waste, in the production of biofuels, such as bioethanol, and to face the problems of environmental pollution.(Villegas, 2018)

It is indicated that the cellulose of R. communis bleached by the aforementioned process and obtained by means of the firing of alkalines (soda-Kraft), can be proposed as a fibrous component of agro-industrial waste, accompanied by long fiber in a range of 40 to 80%. This would represent a decrease in the costs of industrial short fiber (FC), and would favor the use of an unconventional fibrous source, classified as a plant weed.(Rodriguez, Domingues, & Vargas, 2015)

Industrial Waste Flow Diagram

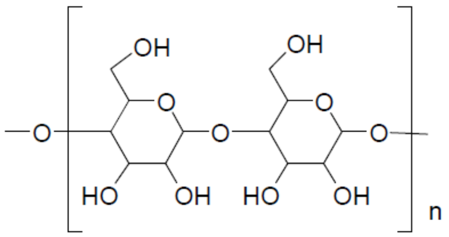


Material for obtaining cellulose in agro-industrial waste

It is the most important source for the processing of cellulose, which is used to produce paper and cardboard. Several studies have shown that it is possible to obtain cellulose from agro-industrial waste such as:

- **Fibre waste**
- **Bagasse**
- **Wood**
- **Bioethanol**
- **Cl**
- **NaClO**
- **ClO2**
- **H2O2**
- **NaHS**
- **Lignin**

Physico-chemical characterization of agro-industrial waste in the cereal sector to obtain cellulose.



celulosa

Cellulose is a polysaccharide composed of glucose units that are linked by glycosidic bonds. On a physical level, cellulose comes in the form of long, resistant fibers, which gives it its mechanical properties. It is insoluble in water and does not form gels, making it suitable for paper and textile applications.(Fernandez A. , 2022)

In terms of its chemical characteristics, cellulose is stable and does not degrade easily. It is resistant to most solvents and acids, although it can be enzymatically hydrolyzed by certain cellulite enzymes. In addition, cellulose is combustible and can react exothermicly with strong oxidizers, making it susceptible to spreading wildfires.(Sanz A. , 2010)

Cellulose is the most abundant organic biomolecule in the biosphere and plays a fundamental role in the structure of plant cells, wood and natural fibers. Its linear structure and the formation of hydrogen bonds between glucose chains contribute to its physicochemical stiffness and strength that make it suitable for use in the manufacture of paper, textiles and other products, as well as being an essential component in the structure of plants and terrestrial biomass.(Moccoci, 2018)

Its main feature is the separation of hemicellulose and lignin using NaOH, and the power process itself, the separation of cellulose fibers by dissolving lignin by fermentation, in both methods the bleaching technique is also described. It aims to promote the understanding of pulp extraction. (Canche, Hermandez, Andrade, & Gémez, 2005)

The application of technologies, their use in agro-industrial waste and the understanding of the extraction of cellulose, thus generating new by-products that promote its recycling and thus reduce the impact on the environment. In order to produce high-quality chemical pastes with high degrees of whiteness, it is necessary to use bleaching methods that continue to lignify the paste initiated at firing and reduce the colour. (Lopez, 2015)

Chips from the stockpile are taken to the chip hopper, where they are impregnated with water vapour to remove their air content (high-pressure impregnating vessel). It is at this stage that an aqueous solution of soda (NaOH) and sodium sulfide (Na2S) called white liquor or bleach begins to be added. (Veronica, 2018)

An equation to calculate the percentage of lignin in cellulose is presented:

$$\%\,Lignina = 0.165 * ik$$

The Kraft process is a very efficient process, although it has the disadvantage of bad odours produced by the emission of thiols and sulphides. Chemical cellulose, thus obtained, is characterized by having a low percentage of lignin and by its resistance, since the cellulose fibers remain intact, are easy to bleach and are not prone to losing their qualities over time.

Procedures for the use of agro-industrial waste and the production of cellulose

The procedure for obtaining bleached Ricinus communis cellulose mixed with industrial fibre for evaluation and incorporation into the manufacture of waste in the cereal sector is described. By means of a factorial model, the Kappa number and viscosity were determined.

Where is the equation for Kappa:

$$k = \frac{P_r(a) - P_r(e)}{1 - P_r(a)}$$

where *Pr(a) is the relative observed agreement among observers, and* Pr(e) is the hypothetical probability of agreement by chance, using the observed data to calculate the probabilities that each observer randomly classifies each category. If the evaluators are in complete agreement, then $k = 1$. If there is no agreement between the raters, different from what would be expected by chance.

While the equation to determine viscosity is as follows:

$$t = \frac{F}{A} = \mu \left(\frac{dv}{dy}\right)$$

Cellulose Extraction Tests

At the laboratory level, the lignocellulosic material is treated with 10% (NaOH) to remove waxes, pectins and resins, cooking is done in a 1000 ml beaker on a hot griddle. When observing the first bubble, let it heat for 10 minutes at 90°C, then let it rest for 20 minutes to cool and wash with normal water; This is followed by another wash with purified water (pH 7) and then manually defibrated. Finally, it is dried in a forced-air stove at 65 °C and allowed to rest.(Jimene & Prieto , 2017)

Cellulose treatment to facilitate its use

They correspond to the methodologies aimed at obtaining cellulose pulp by separating fibers from the different agro-industrial wastes, where lignin can be isolated from lignocellulosic material by different mechanical and/or chemical processes, while the second treats the sample with chemical reagents that involve the dissolution of lignin. leaving cellulose and hemicellulose as insoluble waste.(Cerreño & Caicedo, 2012)

The alkaline treatment is able to separate both hemicellulose and lignin, without having great effects on the other components. In this way, a loss of the crystallinity of the cellulose and partial salvation of the hemicellulose is caused, however, this treatment has the disadvantage that some bases are converted to their salts and cannot be recovered and some of these can be incorporated into the biomass in the treatment process.(Ramirez, 2012)

End Products

The largest consumption of cellulose is for paper and cardboard, secondly, to obtain textile fibers (rayon) and the derivatives acetate and cellulose nitrate. The cellulose fibre used in the manufacture of paper comes from wood, either virgin fibre (which will always be necessary for the paper industry) or recovered fibre. Wood, a natural and renewable resource, is therefore the basic raw material of the paper sector.

Long-staple white cellulose is mainly used to add strength to papers and cardboard, and short-staple white cellulose is used for softness and as a filler. Depending on the proportion in the mixtures, papers are obtained for different uses. There are currently more than 450 varieties of papers according to the classification of the International Pulp and Paper Directory.

3. Conclusion

Cellulose is obtained from a process in which waste from the cereal sector, once ground and crushed, is subjected to high pressures and a temperature of about 140 ºC, which is the glass transition temperature of lignin. This process requires a high energy consumption, 1600 h/T produced. Cellulose is characterized by its high yield, usually between 85% and 95%.

This means that 85 to 95% of the original material (wood) remains in the final product (cellulose fibres). A drawback that derives from this fact is that the remaining lignin in the product is susceptible to oxidation, generating the yellow color that characterizes old newspapers. The main uses of these celluloses are the manufacture of newsprint and lower quality printing and writing papers. This cellulose is less resistant than chemical cellulose, not because of the presence of the remaining lignin, but because the fibers contained in it have been cut in the manufacturing process.

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