International Journal of Business and Industrial Marketing
2021; 4(1): 1-4
http://www.aascit.org/journal/ijbim
ISSN: 2381-117X (Print); ISSN: 2381-1188 (Online)

AASCIT American Association for Science and Technology

Development a Process of Technological Innovation for Industrial Paper Production

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Citation

Lilian Alarcón, Oscar Quiroga and Ignacio Rintoul. Development a Process of Technological Innovation for Industrial Paper Production. *International Journal of Business and Industrial Marketing*. Vol. 4, No. 1, 2021, pp. 1-4.

Received: February 27, 2018; **Accepted**: April 1, 2018; **Published**: March 17, 2021

Abstract: This paper presents a description of an innovative process applied to the production of paper from the use of stem fibers of the banana plant. According to the Organization for Economic Co-operation and Development Oslo Guidelines, innovation is essential for growth in production as well as productivity and is a continuous process that makes changes in products, processes and captures new knowledge. In order to guarantee product (paper) and process (pulp system) innovation, a comparison was made with the mechanical properties of paper obtained from the organic waste with a typed paper commercial use wave produced in a paper industry located in Asunción-Paraguay. The temperature, time and reagents chemical were operational variables selected to comparison of innovative processes. The yield of innovator process analyzed was 52.5%. The results of comparison of processes for obtaining cellulosic pulp indicates that mechanical properties as Stress (N.m/g), Compression in the plane (N) and resistance to compression in the edge (N) increase in comparison with conventional processes (Chemical process to soda and Chemical Process Kraft) and this properties are highly valued by the paper industries for use in corrugating industries. The (pulp system) innovation process presents many technical and economic advantages among alternative processes for paper production.

Keywords: Paper Production, Innovation, Process, Product

1. Introduction

Innovation is considered the first driving force of progress and prosperity. Consequently, an important effort is made to develop new technological knowledge, new process technologies, and new products. However, evidence from small, medium and large company's shows that successful innovation is not only the result of technological innovation but is highly dependent on what is known as innovation management [10].

On the other hand, it can be said that technology is the means by which scientific knowledge is brought to the solution of concrete problems in an effective way. Technology implies creating competencies and is expressed in technological entities that consist of machinery, procedures, and skills [11].

To adapt to market changes, companies must invest in research into new processes, thus being able to improve their production in terms of costs and productivity, or easily produce new products. The Oslo Manual states that process innovation involves the use of methods, equipment and/or new or significantly improved knowledge [8].

The purpose of this paper is to describe an innovative procedure consisting of a new and improved production technique applicable to the production process in the paper sector. On the one hand, this procedure allows obtaining a new product or technological innovation of product that contemplates the technical specifications demanded by the current market. On the other hand, the proposed new paper-making method or procedure represents in itself a technological process innovation.

2. Technical Description of the Process

Pulp paper is the product resulting from the separation of wood fibers or other fibrous materials and is an intermediate product in the overall process of processing raw materials on paper. Their properties, which will have a large impact on those of the final products, paper and cardboard, depend on the source of the fibers and the paste process used, the main objective of which is to release the fibers by destroying or weakening the bonds that keep them together in a well cohesive structure [5].

Lignocellulose materials of forest and agricultural origin are used to manufacture pulp. Wood is currently the lignocellulose material most commonly used in the manufacture of paper pulp in developed countries. Other plants can also be used as raw material, such as straw from a variety of cereals such as wheat, rye, etc.; rice; canes such as bagasse; woody stems from bamboo, flax and hemp; and fibers of seeds, leaves, and bark, such as cotton, abaca, and henequen or sisal. The old paper itself can be recycled, thus constituting a source of raw material for pulp production [3]. This paper also describes the use of the banana plant stem as a raw material to produce pulp.

In the process of making pulp, cellulose fibers are separated from the rest of the wood components, mainly lignin. The main reason for this process is the elimination of lignin, affecting as little as possible the secondary wall of the fibers. The process of pasted or obtaining a suspension of fibers in water consists of several phases [7]:

1) Preparation of the raw material: these are operations such as log washing, cutting, debarking and splintering to facilitate further treatment.
2) Obtaining the pasta: they are made in different ways according to the quality desired.
3) Washing: it is done to remove the dissolved substances that accompany the paste.
4) Scrubbing and conditioning: the fibers are treated to leave them free of foreign matter and with a size and thickness of the fibers suitable thickness for further processing.
5) Bleaching: consists in the elimination of residual lignin and colored components of the paste.

In particular, for the second phase previously indicated for obtaining pulp, there are different types of processes for obtaining pulp, including chemical, mechanical and chemical-mechanical methods. These methods, once applied to the raw material, in this case, the stem of the banana plant, allow obtaining the cellulosic paste, which is then transformed into paper.

In order to obtain the cellulosic paste, a procedure must be carried out to separate the components (lignin and cellulose) of the raw material used, which in this case is the fiber of the stem of the banana plant. The lignin is a polymer that acts as a cement structure in the components such as cellulose, hemicellulose and other components of the vegetable raw material. In this way, in order to achieve the separation of lignin from cellulose, one of the processes mentioned above is applied.

In the chemical method, there are several processes, among which we can list the so-called chemical process to soda, and the Kraft process. The variables of the operative condition of both processes are the temperature, time, the relationship between liquor and active alkali. With the right combination of each variable, lignin is released from cellulose to obtain cellulose pulp or cellulosic fibers for subsequent paper formation [9].

In the mechanical method, cellulosic fibers are released by applying mechanical energy to the vegetable raw material. Thus, the paper obtained through this second process has low mechanical properties, although a high paste yield can be achieved [9].

The chemical method gives a greater mechanical property to the final product, i. e. paper. The chemical method, either the chemical process to soda, or the Kraft formation [4], used for the manufacture of the product paper requires the combination of high temperatures and pressure to achieve a correct delignification of the lignocellulose material, and thus, to obtain the cellulosic pulp for subsequent paper formation [6].

The methodology used to achieve the innovative process consisted in the development of a chemical process, which is characterized by temperatures above the boiling point, but lower than that applied in a process traditional chemistry.

The application of the new process was initially carried out on a laboratory scale and subsequently implemented in a pilot plant, once the values of the operating conditions were obtained. On that occasion, the variety known as *Musa s. p* was used for the banana plant that comes from the Hernando Bertoni Research Center of the city of Caacupé - Paraguay [2].

3. Product Descriptions and Innovative Process

The innovative process consists of improving the method for obtaining cellulosic pastes, for which the operational variables such as temperature and reagent loading are manipulated, with the aim of achieving a correct delignification, which allows the obtaining of pastes and subsequent paper formation corresponding to the resulting innovative product.

3.1. Process Innovation

The innovative process for obtaining cellulosic pastes consists of delignifying the lignocellulosic material from to separation of the fibers of the banana stem from lignin, with lower temperatures and pressures as described above.

Table 1. *Comparison of processes with the developing chemical process [1].*

Variable operative	Chemical process to soda	Chemical Process Kraft	Chemical Process innovative development
Temperature	175°C	176°C	145°C
Time	3 – 4 hour	2 hour	45 minute
Reagents chemicals	10 – 18% of NaOH Efficiency: 50%	8.6% of NaOH; 27.1% of Na_2S and 14.3% of Na_2CO_3 to 10 al 15% Efficiency: 50%	5.4 – 10.5% of NaOH Efficiency: 52.5%

In Table 1 shows a comparison from the point of view of the yield of the cellulosic paste obtained according to the process applied. It should be noted that in the innovative chemical process, a combination of low temperatures and digestion time, with the aim of achieving a higher yield compared to other processes that are presented in the traditional method. In addition, this process produced a cellulose pulp that can produce a paper with excellent mechanical properties, which are very interesting for the production of cardboard boxes.

In order to achieve this innovative chemical process, tests were carried out in laboratories and later in the pilot plant. In each test, adjustments were made in the preparation of the fibrous material and in the combination of pulping process factors: alkaline load, sulfur content, liquor ratio, time and temperature [2].

3.2. Product Innovation

Once the cellulosic paste is obtained, the paper is formed into standardized sheet formers used in a paper industry. The type of paper obtained corresponds to a wave paper, a corrugating paper.

In Figure 1 shows the position of the wave paper on a corrugated board. It was classified within this type of paper, due to its physical texture and mechanical properties (Asociación de Fabricantes de Envases y Cartón Ondulado).

Finally, from the paper obtained in this work, the mechanical properties of the wave type produced by the paper industry are compared. These properties are: tensile strength and compressive strength of wave paper. These properties are defined by the paper industry [6].

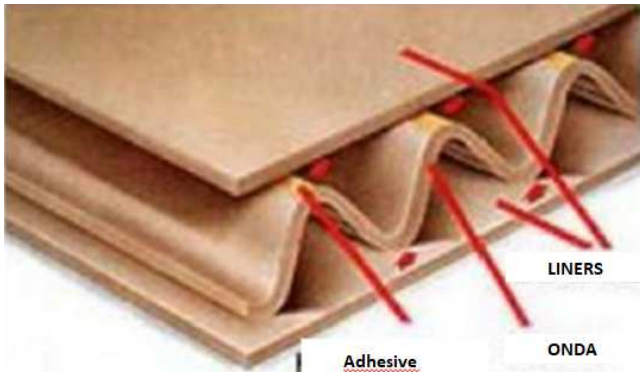

Figure 1. *Location of a wave paper in corrugated cardboard.*

In the Table 2 shows the comparison of mechanical properties considering the following aspects [2]:

Paper obtained with the innovative chemical process developed.

Wave-type commercial paper from a paper industry.

It is highlighted that the corresponding innovative product is obtained from banana stem fibers, and has optimal properties that can be used in a corrugator industry.

Table 2. *Processes for obtaining cellulosic pulp.*

Mechanical properties	Innovator chemical process	Process of the industry	Result
Stress (N.m/g)	113	40.37	Value increased by 181% in in relation to the paper compared, is relevant on the machine corrugator in such a way as not to cause paper breakage losses on the corrugating machine during corrugated process
Compression in the plane (N)	209	123	Value increased by 70%.27%, the same indicates resistance potential for flat compression corrugated board that is manufactured from this paper.
Resistance to compression in the edge (N)	214	158	Value increased by 35%. 67% in relation to paper formed is of paramount importance for the corrugated cardboard boxes this property for the stacking of boxes.

4. Applications and Potential Markets for Product and Innovative Process

The main application of this type of paper obtained with the mechanical properties presented in Table 2, corresponds to one of the wave type, which is widely used in the corrugator industry, the manufacturers of cardboard boxes, among others.

As far as the innovative process is concerned, the main market is mainly focused on the paper industry, dedicated to producing different types of papers to supply mainly corrugators. The innovative chemical process is mainly underscored by the minimum demand in the operational variables compared to the variables of the processes currently applied.

1. Cost estimates

An estimate of the costs for obtaining one kilogram of paper was made from the innovative method proposed according to the raw material chosen, i. e. the fibers of the banana stem. Subsequently, to these cost values were compared with the final price of a commercial paper of the wave type produced by a paper industry, with similar

characteristics to the paper obtained in the present work.

2. Conclusions based on the comparison carried out are highlighted below [1]:
   1) In order to obtain 1 kilogram of paper with the technical specifications required by the market, 55% of costs are incurred to obtain paper with the innovative method developed.
   2) That is to say, costs are reduced by 45% with the innovative method developed in comparison to the wave-type paper that is manufactured by a paper industry.

5. Conclusions

The manipulation of variables of operating conditions, such as time, temperature and pressure, triggered an innovative process to obtain a cellulosic paste. The same presented in the studies carried out in laboratory and pilot plant a yield of 52.5% of cellulose paste, a value higher than the yield from a chemical process to soda or Kraft, both corresponding to 50%.

It also produced a type of paper with properties highly valued by the paper industries. In addition, the mechanical properties obtained are satisfactory for use in the corrugating industries.

The costs of the process and innovative product are highly advantageous compared to the costs of a current process for obtaining the final product.

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