Addis Ababa University

Addis Ababa Institute of Technology

School of Chemical and Bio Engineering

Investigation on Recycling of Waste Beer Label Paper

By

Eden Amdebirhan

M.Sc Thesis

A Thesis submitted to the school of chemical and Bio Engineering presented in partial fulfillment of the requirement for the degree of masters of Science (Environmental Engineering), Addis Ababa Institute of Technology, Addis Ababa University, and Addis Ababa, Ethiopia

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DECLARATION

I declare that the thesis for the M.Sc. degree at the university of Addis Ababa, here by submitted by me ,is my original work and has not previously been submitted for the degree at this or any other university, that all resources of materials used for this thesis have been duly acknowledged.

Name: Eden Amdebirhan,

Signature: …………………………………..

Date of submission: ………………………

This thesis has been submitted for examination with my approval as a university advisor.

Name: Dr. Shimels Kebede

Signature: ……………………

Date………………………………

Abstract

The solid wastes generated from beer industries during beer packaging in which each bottle has to be labeled with a paper then turned to wastes after usage.

In this study repulping of waste beer label paper was carried out by repulping Heniken's waste beer label and blended it with used A_4 sized paper found in AAiT. The study was conducted under different conditions with the influence of mixing ratio (0, 25 and 50 %), drying temperature (100,110 and 120^{0}C) and drying time (60, 90 and 120 min) on repulp yield properties. Results indicated that mixing ratio and drying time had a significant influence on repulp yield. Likewise the optimum result with respect to yield was obtained by 50% mixing ratio, 120^{0}C drying temperature and 120 min drying time.

At the optimum operating conditions the physical tests of hand sheets made from repulping of mixed beer label paper was carried out at Ethiopian Pulp and Paper Factory resulting 66.3 Nm/g, 6.26 mNm^2/g and 5.421 kN/g tensile index , tear index and burst index respectively..

In general, results based on morphological and repuling analysis indicated that wasted beer label fibers are promising fibrous raw material for the paper production and have tremendous results for environmental challenges in the brewing industries.

Key word: *beer label paper, recycling of paper, repulping, pulp and paper production*

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Table of Content

List of Figures

List of Tables

List of Abbreviations

AAiT	Addis Ababa Institute of Technology
CEPI	Confederation of European Paper Industries
RP	Recycled Paper
PSA	Pressure Sensitive Adhesives
PSL	Pressure Sensitive Labels
SW	Solid Waste
SWMS	Solid Waste Management System
TAPPI	Technical Association of the Pulp and Paper Industry
CSF	Canadian Standard of Freeness
CD	Cross Direction
MD	Machine Direction
TMP	Thermo Mechanical Pulp
RSM	Response Surface Methodology
EPA	Environmental Protection Agency

1. Introduction

1.1. Background

Paper comprises a network of plant fibers laid down as a flat sheet that is made from a suspension of plant tissues in water, known as pulp. 'Paper'' is derived from ''papyrus,'' the Ancient Greek word or Cyperus papyrus. The plant fiber is reusable for six to seven times (Villanueva A & Wenzel H, 2007).Paper is made by pulping wood, bleaching this pulp and then spreading it out into sheets to make it into paper. Hence, the demand and use of paper is rapidly increasing in the global market and have marked the levels of civilization and development of many societies. Paper in society is used in a variety of every day applications, from paper for writing to paperboard as packaging material with security of goods in transit; protection of human health and sanitation in form of tissues and sanitary paper products (Villanueva A & Wenzel H, 2007).

Wood is considered the primary raw material and the major source of pulp in paper production. Global production of paper and paper board is 406 million tons per year which is derived from 225 million tones recycled paper, 176 million tones wood pulp and 12 million tones other fibers pulp. Hence, the demand for recyclable waste paper is rapidly increasing in the global market of pulp production (FAO U. , 2016).

The recycling of solid wastes such as paper, glass, plastic, and so on, turns wastes into resources and contributes significantly in sustainable environment (Chen HW, Yu RF, Liaw SL, Huang WC & Zaman AU, 2010 ; Zaman, 2010).

Paper product manufacturing involves a variety of chemicals used either directly in paper and pulp production or in the conversion processes that follow. Due to economic and environmental initiatives, paper recycling rates continue to rise to maximize the efficient use of wood material and limit its impact on biomass availability; the paper industry prolongs the life of its wood resources by reusing paper as feedstock in its production process.

Today, Paper recycling is one of the most well-established recycling schemes applied to waste materials. Recycled paper is an integral part of paper and pulp production, with estimated utilization for recycling ,in Europe, recycling has increased by nearly 20% within the last decade or so, reaching a level of almost 72% in 2012 (an increase of 20% from 2000;) (CEPI, 2013a).

In addition to recycled paper being an important raw material for the paper industry (CEPI, 2013), it has also been demonstrated in several studies that paper recycling may offer significant environmental benefits in a lifecycle perspective (Laurijssen, J., Marsidi, M., Westenbroek, A., Worrell, E., Faaij, A.,, 2010). Thus, paper recycling may be regarded as beneficial from both a resource and an environmental perspective and should be promoted as much as possible (Pivnenko, Waste Paper for Recycling, 2015). It has a number of important benefits including saving trees from being cut down, It requires 60 percent less energy and 80 percent less water to produce than virgin paper, it saves waste paper from occupying landfill and producing methane as it breaks down, it generates 95 percent less air pollution, recycling one ton of paper on average saves 26,500 liters of water, about 318 liters of oil, and 4,100 kilowatt-hours of electricity (Lennart N. , Per, Lars , Siarhei , & Audrone , 2007) . Recycling has plenty of room for improvement, with only 63 percent of produced paper being recovered.

Around two thirds of all paper products in the US are now recovered and recycled, although it does not all become new paper. After repeated processing the fibers become too short for the production of new paper.

The consumption of recycled paper has been in continuous growth during the past decades. According to the CEPI, the use of recovered paper was almost even with the use of virgin fiber in 2005. This development has been boosted by technological progress and the good price competitiveness of recycled fiber, and also by environmental awareness that has influenced the demand for recycled paper. The European paper industry suffered a very difficult year in 2009 during which the industry encountered more down-time and capacity closures as a result of the weakened global economy. Recycled paper utilization in Europe decreased in 2009, but exports of recycled paper to countries outside CEPI continued to rise, especially to Asian markets (96.3%recycled). However, recycling rate expressed as “volume of paper recycling/volume of paper consumption” resulted in a record high 72.2% recycling rate after having reached 66.7%

the year before (Hujala, Puumalainen, Tuppura, & Toppinen, 2010; CEPI, 2011;Huhtala & Samakovlis, 2002; CEPI, 2006; CEPI, 2010)

The highest paper recycling rate in the world has been achieved by Sweden, at 79 percent. The recycling rate in Germany 74 percent, Finland 72 percent, and Japan about 65 percent. The United States, for comparison, has a 48.1 percent paper recycling rate. It is clear, therefore, that although there is room for further improvement in the overall rate of paper recycling, the U.S. commercial paper recycling industry fares very well (69 percent recycling rate) with respect to the rest of the developed world (CEPI, 2011)

According to CEPI the recent paper and board production was stable in 2018, compared to the previous year, total production in 2018 reached 92.2 million tons. The year 2018 saw new capacities coming on stream. Combined with the upgrade of existing machines, this translated in a net capacity increase of 1.3 million tons. The production stability observed in Europe contrasts with the reduced global paper and board production, 0.6% in 2018 compared to 2017, to 417 million tones giving to very first estimates. This reduction was mainly driven by China, whose production decreased by close to 4%.Paper and board production in Japan, South Korea and the United States has also declined, whilst production in Canada, Russia and several emerging countries (India, Indonesia and Mexico, for instance) increased. With an increasing demand for cellulose pulp and solid waste too decreasing supply of wood, many countries all over the world are using recycling of pulp to produce paper. These sectors will continue on a sustainable path in paper recycling, making it possible to reach the new target of a 74% recycling rate by 2020.

Pulps from beer label as a waste consist of a mixture of paper grades with water proof properties, gluey property; and mixed with caustic soda which is the result of bottle washing process and variety composition from washing machine. Returnable bottles demand labeling that stays firmly in place during use, and which can be removed easily after return to enable reuse of the bottles. Wash-off label technology is suitable for all returnable glass bottles, using an innovative dual layer construction and a unique adhesive.

The label detaches easily from the bottle in a conventional bottle washer, making Wash-off the portfolio of choice for beverage manufacturers who need a reliable clear-on-clear ‘no label’ look for returnable bottles.

Nowadays, packaging grade papers contain 60-100% recycled fibers. Together with cleanliness of the pulp, the morphological properties of the recycled fibers are the greatest concerns of paper recycling. Recycled fibers tend to be broken or damaged and they have different physical properties than virgin fibers (e.g. micro-fibrils on the surface of fibers tend to be collapsed) resulting to weaker inter-fiber bonding and consequently to lower strength in paper. The use of modern process technology (mechanical refining, coatings, deinking, bonding adhesives etc.) are additional cost thus necessary to compensate for inherent disadvantages of recycled fibers.

The thesis aims to solve the poor solid waste management specifically the beer label which is dispose to the environment after washing process as waste beer label in Ethiopia brewery industry by recycling those wastes and producing valuable product which is paper and paperboard that has the significant role for the company's, societies and the environment.

1.2 Statement of the problem

In Ethiopia, the brewing sector holds a strategic economic position with annual beer production exceeding 20-25 hectoliter beer and corresponding yeast, grain and hop producing much wastewater, spent grain, spent yeast and other packaging solid wastes (ABREW, 2004). The value of the environment has been taken for granted by many beer industries. Most technologically advanced equipment and other human activities have extremely damaged the environment. With this complexity, beer industries haven't been able to establish a system which ensures all are obeying the need for environmental sustainability. Environmental issues are a critical factor for today's industry competitiveness. Indeed, the society and the individual could set common engagement about the context of protecting the environment (Abass , 2012).

Solid wastes include label pulp from the washing of returnable bottles, broken glass, cardboard, bottle caps, and wood that is usually disposed of at sanitary landfills. These wastes should be avoided or at least limited since they are not simple papers but wet-strength paper impregnated with ink and caustic solution (Abass , 2012).

Ethiopian Brewing industry has no focus on recycling of by-products that are generated throughout the brewing processes; and has no constant and well developed margins where they can be recycled or disposed.

Among those Brewing industries, Heineken Ethiopia is the biggest brewery which produces as higher as 7 million hectoliters beer at Walia, Harar, and Bedele that overtake BGI as Ethiopia's biggest beer production company. Solid wastes are generated in every packaging process, throughout washing almost all bottles, the neck and side label pass through label removal phases, and the removed label should be managed based on Solid Waste Management System. However there is no strong SWMS in the country that results challenges for the environment.

Due to its highest production capacity and having concern in identifying the problem and seek for sustainable solution Heineken Ethiopia was selected as study area. It disposes the Solid wastes (wasted label paper) to the area called "kosh". kosh is a large open landfill which receives rubbish and waste from Addis Abeba, It has been in operation for about 50 years but shrinking as the result of regulation (Caroline, 2014).

On the other hand pulp and paper companies in Ethiopia are totally dependent on an imported pulp and convert to paper-based products and the raw material for the pulp is wood fibers However, trees as raw material are not preferable due to ecological effects and cos, more over Recycling is poor culture in the country results a burden to the environment and recycling this wasted beer label paper is the alternative option to reduce this saddle.

Therefore, primary goal of this paper is to study how to change these solid wastes to useable paper and to provide suggestions to use the recycled wasted beer label as packaging paper.

1.3 Objective

1.3.1 .General objective

The general objective of this study is recycling of wastes beer label paper to usable paper products.

1.3.2. Specific objectives

- ✓ To characterize the physical and chemical properties of wastes beer label.
- ✓ To determine the required pulping parameters such as time, temperature and waste paper classification (ratio).
- ✓ To prepare good quality pulp from waste beer label and produce paper.
- ✓ To evaluate the quality of paper product produced from the pulp.

1.4. Significance of the study

This study has benefits as it goes without saying that economy will always be a primary concern when it comes to developing sheltering solutions. Nowadays, in paper making industry, the environmental problems have brought forward the need for cleaner technology where the new technique have been introduced to recover the wasted paper as raw materials for paper making. The cleaner technology or green technology is applied to achieve increased production with minimum effect especially on the environment and lessen the disposal cost, steadiness risks and resource cost resulting in a declined burden on the natural environment and also increase the profits in pulp and paper-based industries . The abundance of brewer industry and lack of pulp and paper production in Ethiopia made the responsibility for the use of waste label as raw material for pulp and paper production.

This is not just to the advantage of the relief organization but could also have great potential in offering the end user with an adaptive longer term use.

- This study showed that waste paper is an alternative raw material source for pulp and paper production.
- Helps to develop a culture of using wastes beer label for production of paper and packaging materials, thus escalate protecting of our ecology and environment.
- The recycled paper products as a source of fiber to reduce the need for virgin fibre (this also requires less energy and water for conversion).
- It can show that there is an option to minimize solid waste that will be deposed to the environment in beer industry's using this resource for further processing is one way of waste minimizing mechanism.
- It creates new job opportunities during paper and packaging production.
- It decreases importing of pulp which will save foreign currency.

1.5 Scope of the Study

The main focus of this thesis was to collect, identify, measure the wasted beer label and characterize its physical and Chemical properties, to state all the necessary pulping parameters and determining the optimal pulping conditions for good quantity of re pulp up to test of paper sheets based on the optimum re pulp yield.

2. Literature Review

2.1. Global pulp and paper production

The primary raw material for the paper production is pulp fibers obtaining by a complicated physical and/or chemical process from natural materials, mainly from wood or other cellulose fibers include agricultural residues and recycled papers. Paper is made from cellulose fibers, which can be produced by pulped wood, recovered paper or a mix of other materials like cotton, straw, grasses or sugar cane (Khantayanuwong, Toshiharu, E, & Fumihiko, O, 2002; Jahan, 2003; Hubbe & Zhang, M, 2005 ; Garg & Singh, S.P, 2006).

There is a long tradition in Europe of producing paper from recycled materials. Between 1250AD and 1875AD paper was made utilizing fibers reclaimed from flax, hemp and cotton. However from around 1860 virgin fibers derived from wood pulp were used. These cellulose fibers were obtained from both chemical and mechanical means. Since 1950 there has been an increasing utilization of recycled wood fibers in both paper and board production. The production of recycled newsprint began in the late 1960s with manufacturers using about 60% recycled fiber with 40% virgin fiber. Since that time the drive to use less of the expensive virgin fiber has resulted in newsprint being produced from 100% recycled fiber. In more recent years attention has turned to the use of recycled fibers in higher quality printing papers. Currently there are many examples of both coated and uncoated papers being manufactured that contain up to 80% recycled fiber (Fricker, Manning, & Thompson, 2007).

The two largest paper and paperboard producers in 2017 were China (111 million tons) and the USA (72 million tons). Their combined production accounted for 45 percent of global Production. The other three largest producers were Japan (26 million tone), Germany (23 million tons) and India (14 million tons), which accounted for another 16 percent of global production. In terms of future capacity, future trends in the paper and board industry show a stable production over the next years (FAO, 2016).

Since 2012, the United States and Japan have both been eclipsed by China, whose production expanded rapidly. A slight dip in 2015, to 101.1 million tons, was only the second time that production declined in China in the last half-century. Accompanying the growth in Chinese output was a shift from non-wood fibers such as cereal straws and bamboo to wood fibers, the development of large-scale tree plantations, and the consolidation of a once fragmented industry (FAO, 2016).

For many years Canada was the second or third largest producer. However, it was bypassed not only by China but also by Germany and South Korea .After 2015; Canada's output plummeted by almost half, from 20.9 million tons to 11.3 million tons. Close behind are Sweden and Finland, as well as Brazil, India, and Indonesia—three countries whose production has risen strongly(Ibid).the top 11 producers together accounted for three quarters of global production (Deloitte, 2013)

Global exports of paper and paperboard climbed more than nine fold between 1961 and 2010 to a Volume of 117.6 million tons, but trade flows have since been unstable, declining to 109.4 million tons in 2014 .Relative to production, exports almost doubled from about 17 percent in the early 1960s to 31.2 percent in 2004, then dropped to 27–28 percent (Calculated from ibid). By value, paper exports followed a less steady trajectory, but they rose from about $2.1 billion in 1961 to $102.6 billion in 2014, with a peak at $110.8 billion in 2015 (FAO, 2016).

Paper consumption in North America, Europe, and Japan has declined in recent years, shifting to other parts of the world. The share used in industrial countries fell from 66 percent of global demand in 1999to 42 percent in 2015 (Brandt, 2014).China's share rose from 9 percent to 25 percent during the same period; in 2012, all of Asia accounted for 46.1 percent, compared with 24.2 percent in Europe and 19.4 percent in North America, while the rest of world came to only 10.4 percent (Industries, Consumption shares in 2012, 2013).

Fibers production is very energy demanding and at the manufacturing process there are used many of the chemical matters which are very problematic from view point of the environment protection. The suitable alternative is obtaining of the pulp fibers from already made paper. This process is far less demanding on energy and chemicals utilization (Cabalova, Frantisek Kacik, Anton Geffert , & Danica Kacikova, 2011).The pulp and paper industry is a large energy and water consumer, as well as a user of toxic chemicals. In the United States, the paper industry is the third largest energy user among manufacturing industries, accounting for 11 percent of energy consumption (Administration, 2016).Reducing the paper industry's environmental footprint requires continued progress in minimizing unnecessary paper consumption and avoiding waste, in raising paper recovery and recycled content, in ensuring that virgin fiber is derived from sustainable forestry and logging operations, and in using less polluting and less energy-intensive paper production methods (EPN, 2011).

On average fibers can be recycled five to seven times before they become unusable. Recycled paper with long fibers (such as office printing paper) is generally of higher value than paper with short fibers (such as newsprint) (U.SEPA, 2012.).

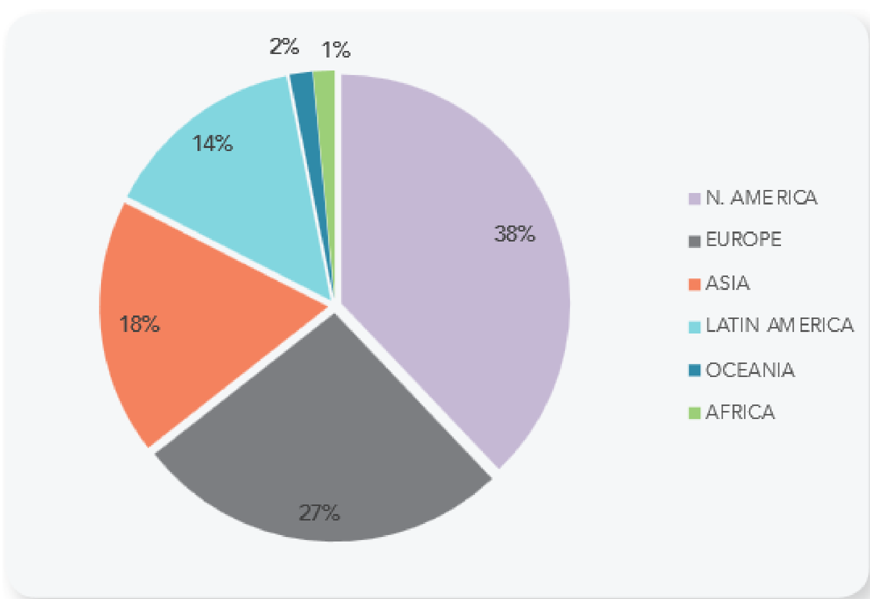

Figure 1.1: Global pulp and paper production (FAO).

2.2. Raw material for paper making

This literature review first summarizes the nature of cellulose fibers used for papermaking and the techniques used to manufacture these fibers from recycle waste paper specifically waste beer label.

Paper manufactured from wood is composed primarily of cellulose fibers; it also can contain hemicelluloses, lignin, and extractives that were present in the wood. The ratio of these components varies depending on the species of wood, as hardwoods and softwoods. In addition, there are several common additives used in the paper industry to enhance the properties of the manufactured paper. The type of wood used to make pulp, the pulping method, and the additives used all affect the final properties of a paper sheet (Adam, 2008)

2.2.1. Cellulose

Cellulose, the primary component of wood, is a polymer chain formed a linkage of two glucose molecules base units. The cellulose units form a long, flat polymer chain that exposes a number of hydroxyl groups, bonding sites that allow the polymer chain to form a large amount of hydrogen bonds (Smook, 1982).

In nature, the cellulose chains are oriented in a parallel structure, creating "micro fibrils" within the cell wall (Brown, 2002). From these basic structures, an entire fiber is assembled (Smook, 1982).

2.2.2. Hemicelluloses

Hemicelluloses are amorphous polymers consisting of 5- and 6- carbon sugars and uronic acids that are roughly 100 to 200 units long (Christensen & H.W. Giertz, 1965).These sugars (glucose, mannose, and hexoses, and xylose and arabinose and acids form a myriad of different polymeric structures, some of which associate closely with cellulose and others with lignin within the wood structure (Smook, 1982).

Hemicelluloses are the most water soluble of the main components of wood. Because of their short chain length and prevalence of hydrogen bonds, they swell greatly and absorb a good quantity of water when wet (Christensen & H.W. Giertz, 1965). However, hemicelluloses are also the most easily degraded compound present in wood. Any pulping process degrades or dissolves at least some of the hemicelluloses present in wood. During high yield pulping, only a small fraction of hemicelluloses may be removed, but in low yield pulping the majority of hemicelluloses are often lost (Adam, 2008)

2.2.3. Lignin

Lignin is a hydrophobic amorphous polymer consisting of phenyl propane monomers (Clark, 1985). Lignin polymers have a high atomic mass, but the degree of polymerization is often hard to determine because of the irregularity of the polymer structure (Institute, 2008).polymer often consists of random, connected substructures constructed from the monomer units. This randomness prevents the lignin polymers from forming crystalline structures, rendering the polymer mass completely amorphous. In wood, lignin fills the cell wall, binding the cellulose fibers and hemicelluloses together (Biermann, Handbook of Pulping and Papermaking, 1996). The majority of lignin coats the fiber surfaces, but some lignin exists within the fibers (Adam, 2008)

2.2.4. Extractives

Wood also contains extractives in small amounts (Biermann & Clark, 1996) . These extractives, such as resins, fatty acids, and alcohols, are mostly soluble in water or neutral organic solvents. They are liberated from the wood during the pulping process, and are often separated out and collected as by products (Adam, 2008).

2.3. Beer label paper

Returnable bottles demand labelling that stays firmly in place during use, and which can be removed easily after return to enable reuse of the bottles. The label detaches easily from the bottle in a conventional bottle washer, making Wash-off the portfolio of choice for beverage manufacturers who need a reliable clear-on-clear ‘no label’ look for returnable bottles (Union, 2017).

There are various types of label papers that can be selected to represent a product authentically and to its best advantage. The range includes both non-coated and natural papers, simple coated papers and high-gloss varieties. Cast-coated papers have an extremely smooth high-gloss Cast- and have a considerably longer penetration time than machine-coated surface, uncoated label papers have a slightly rougher reverse side compared with machine-coated papers giving this fine paper its unique character. The quality of the printed result depends largely on how the ink dries on the paper. (John , 2016)

Beverage labels can be divided in two types. There are the craft beer labels, which are paper-based labels, with natural or coated paper face stock, commonly printed in four-color. The other type is premium labels, for which clear-on-clear materials and biaxially-oriented polypropylene (BoPP) (Weymans, 2017).

As waste beer label paper are generally short fibered, it is not possible to produce papers of substantial strength from pulps based on the threated label paper alone because of the short fiber length and the change in the basic fiber characteristics (strength, length, swelling, bonding potential, waterproofing and inking) has been assumed to be the source of reduction in strength properties.

During the past two decades, numerous studies have been conducted on the potential of papermaking from recycled fibers. Most studies have shown that the strength properties of fibers and paper are reduced upon recycling (Ellis & Sedlachek, 1993).

2.4. Papermaking

Cellulose fibers must be released from the wood structure in order to manufacture paper. There are a variety of pulping methods, including chemical methods that have a low yield but are considered to produce better paper to mechanical methods that have a high yield but produce lower quality paper with lower strength properties (Biermann & Smook, 1996)

2.4.1. Kraft Pulping

Chemical pulping methods use chemical treatments to free the cellulose from the cell wall of the wood. Because hemicellulose chains are more water-soluble than cellulose, the bulk of the hemicelluloses dissolve and are removed from the fiber structure during chemical pulping (Smook, 1982).The majority of the lignin present in wood is dissolved and de-polymerized, allowing for the easy separation of the cellulose fibers (Biermann & J.d.A, 1996).The most common method of chemical pulping is kraft pulping, which was patented in 1870 and has since come to account for more than 80% of the world's chemical pulp while sulfite pulping, the other major method of chemical pulping, is employed less frequently (Kleppe & P.J, 1970).Kraft pulping uses sodium hydroxide and sodium sulfide to delignify the wood and free the cellulose chains. In most kraft pulps, the lignin content of the wood is reduced by at least 50%, which results in the loss of at least 50% of the hemicelluloses and 10% to 15% of the cellulose, resulting in a total yield of less than 50% of pulp from the wood (Kleppe J. P., 1970). The removal of the lignin, a hydrophobic compound, allows for excellent bonding between the hydrophilic cellulose fibers, giving paper sheets of chemically processed pulps a much higher strength than equivalent sheets of mechanical pulp (Adam, 2008) .

2.4.2. Thermo mechanical Pulping

Mechanical pulping uses grinding or other mechanical action to release the cellulose fibers. Thermomechanical pulp (TMP) is made by heating the wood chips with pressurized steam before grinding. The grinding action separates the fibers without removing the bulk of the lignin or hemicelluloses, resulting in a very high yield (up to 97%) (Sjostrom, 1993). Mechanical pulps form paper with high opacity and good printability, but it has lower strength than an equivalent sheet of kraft pulp, and it discolors upon exposure to light due to the presence of lignin and lignin derivatives (Smook, 1982) . For these reasons, it is commonly used to make newsprint and other papers of low quality (Adam, 2008).

2.4.3. Refining

Pulps are commonly refined to increase their ability to form inter fiber bonds and strengthen the resulting sheet of paper. The refining process uses mechanical action to deform and shear cellulose fibers, increasing the ability of the fibers to bond and the strength of the resulting sheet (Batchelor, 1999; Emerton, 1957; Giertz, 1957; Hietanen & K, 1990).The mechanical action of the refining process breaks the bonds holding cellulose fibers together, creating new fibrils and micro fibrils as potential bonding sites. The effect of the refining process depends on several factors, including the composition and swell ability of the pulp and fiber as well as the conditions (such as pulp pH and consistency) under which the refining occurs (Hietanen & K, 1990).Refined fibers demonstrate an increased ability to retain water and form sheets of increased tensile and burst strength, but they sacrifice drainage and tear strength and the fibers may be cut and irreversibly damaged by the refining process (Giertz, , 1957). Likewise, there is an upper limit to the increase in paper properties gained by refining. Because refining uses mechanical action to break the bonds holding the fibers together over-refining can destroy the fiber structure entirely (Hietanen & K, 1990).

2.4.4. Bonding

The strength of the bond between cellulose fibers helps determine the strength of the resulting sheet of paper. Fibers join together by forming hydrogen bonds and the strength of the sheet can be correlated to the number of inter fiber bonds formed. Although there are a large number of hydroxyl groups in cellulose chains, the majorities of these are taken up by internal bonding and are unavailable to form inter fiber bonds. In order to achieve a strong sheet, the fibers must have a large number of free hydroxyl groups and also be able to bring them into contact (Campbell, 1959).

The amorphous areas of the cellulose chain are hydrophilic and swell when wet, allowing for a flexible structure, while the crystalline areas remain rigid and do not allow water penetration. In order to form strong inter fiber bonds, the fibers must have amorphous regions, allowing for fiber entanglement to bring hydroxyl groups together and allow hydrogen bonding as the pulp dries. Studies have shown that a larger average fiber pore size is linked to swellability and increased sheet strength. Water penetration into the internal areas of the fiber greatly enhances the efficacy of the fiber consolidation process during paper formation, directly contributing to the number of hydrogen bonds formed (Kerekes, R, & P, 1996).

2.4.5. Papermaking Additives

The addition of fillers and other additives greatly affects the properties of a paper sheet. Mineral fillers, such as clay, talc, and titanium dioxide, are added to the pulp before the paper sheet is formed to enhance the optical properties of a sheet, increasing brightness and opacity, and fill in the gaps between fibers, creating a smoother, denser sheet (Smook, 1982) .

2.4.6. Fiber Properties of Recycled pulp

Fibers are particles that have one dimension considerably larger than the other two. Fibers are selected according to their aspect ratio i.e., the ratio of the large dimension to one of the small dimensions. If no other criteria are used, then materials that might not normally be considered fibrous may contain a fraction of particles that meet the criteria for fibers (Gedefaw, 2015)**.**

Short fibers do not produce good surface contact and fiber-to-fiber bonding. The value of fiber diameter affects the tear resistance as the ratio of fiber length to the fiber diameter increases the tear resistance. Thin walled cells collapse readily to form dense, well-boded paper, low in tear but high in other strength properties. The Runkel ratio and flexibility coefficient are important indices to determine the suitability of material for pulp and papermaking. Low Runkel ratio is expected to have an inevitably positive effect on tensile and bursting strengths as well on folding strength (X.S. Chai & J.Y. Zhu, 2014)

2.4.6.1. Determination of Fabre Length

Fiber length is dependent upon the species of wood, but is generally longer for softwood fibers than hardwood fibers. However, mechanical damage to the fibers from pulping and refining can cause small pieces of the fiber to break off, increasing the fines content of the pulp and decreasing the average fiber length. Monitoring both the fiber length and fines content is a method to determine the amount of mechanical damage to a fiber sample due to processing (Brindha , Vinodhini , & Alarmelumangai , 2012)

2.4.7. Morphological Characteristics of beer label paper

Morphological properties of the recycled fibres are the greatest concerns of paper recycling (Mckinney, 1995). Recycled fibres tend to be broken or damaged and they have different physical properties than virgin fibres (e.g. micro-fibrils on the surface of fibres tend to be collapsed) resulting to weaker inter-fibre bonding and consequently to lower strength in paper (Eastwood & Clarke, 1978). The use of modern process technology (mechanical refining, coatings, deinking, bonding Adhesives etc.) and, thus, additional cost is necessary to compensate for inherent disadvantages of recycled fibres (S, E, & D, 2007).

The physical properties of recycled fibres have a strong influence on the papermaking potential of the corresponding pulps, and on most of the end use properties of the final paper products (Silva, et al., 2008). Cellulosic fibres are the majority components of the pulp and have a strong influence on the final paper properties. Two important characteristics of the fibres are length (100-10.000 µm) and width (5 -75 µm). Ratio is defined as the relation between the fibre length and the fibre diameter. Larger ratios will give pulps with higher mechanical properties, such as strength and toughness (Lauke & S. Fu, 1999). Fibre width and wall thickness affects the flexibility of the fibres and their tendency to collapse in the paper production process, affecting by extension, the properties of the final paper (Kibblewhite, R. Evans, & M.J.C. Riddell, 1995).

Fines are elements which length is less than 100 µm and have a width under 5 µm. Fines content is mainly determined by the kind of cooking process of the virgin fibre, by the relationship fibre/fillers in the recycled fibres and by the refining degree for both of them. This parameter is very important in papermaking, since it limits strongly the drainage rate and the paper bulk properties; also, it is related to the optical and strength properties (Seth, 2000).but Most recycled pulps are produced with knowledge as to approximately which species or species groups are included and numerous studies have been carried out in order to understand the relationships between the characteristics of constituent fibres and paper properties (Paavilainen , 1991) .This does obviously not apply to recovered pulps, which contain a mixture of several wood and non-wood fibre types that have been produced with a variety of pulping methods. The difficulty of predicting the properties of paper and paper products from recovered pulps puts several limitations in their effective utilization and together with purity of the pulp, the morphological properties of the recycled fibres are the greatest concerns of paper recycling (Abubakr, Scott , & Klungness , 1995) .

2.5. Paper Recycling

Environmental concerns and a shortage of raw materials have paved the way for the need of recycling. Recycled fiber comes from various sources and requires the fiber to be clean of impurities, since it is further used for the production of cardboard, packaging and newsprint paper grades, office paper, and hygiene paper (Retner, 2008).

Paper recycling most often involves mixing used/old paper with water and chemicals to break it down. It is then chopped up and heated, which breaks it down further into strands of resulting mixture is called pulp.

According to FAO, recycled paper production (which includes residues from production processes and post-consumer recycling) was 215 million tons in 2015, equal to 54 percent of total world paper supply. This is up from about 20 percent in the early 1960s. The leading producers of recycled paper in 2017 were China and the United States (with 23 and 21 percent of the global total, respectively).They were followed by Japan 10 %, Germany 7 %, South Korea 4 %, and the United Kingdom 4 %.About a quarter of recovered paper is traded internationally (shipped mostly to Asia), up from just 6 percent in 1970.

Recycled paper is further used to produce different paper grades such as cardboard, packaging grades, office paper, newsprint and hygiene paper. In the U.S. alone, the overall recovery of paper and paperboard was 66.8% in 2015, according to 2015 statistics done by American Forest and Paper Association. It is forecasted that in the future, the trend for recycling and recovery will significantly increase (Renner, 2015).

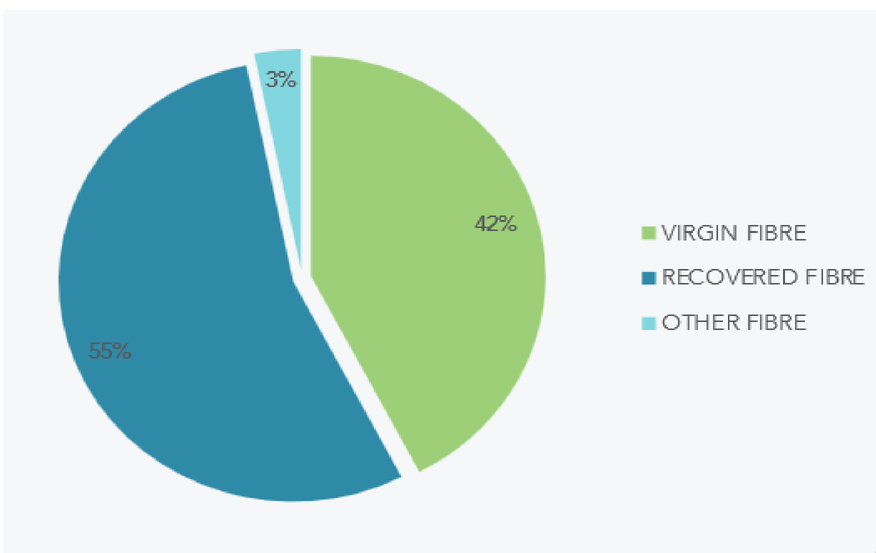

Figure 1.2: Global pulp production, by fibre source (FAO**).**

2.5.1. Paper recycling Process

The recycling of paper is the process by which waste paper is turned into new paper products. The first large-scale paper recycling is believed to take place during the World War I in the U.S. In the Second World War, paper recycling once again received a significant boost caused by the need for materials. With the passage of time, the paper recycling rate slowly increased and according to sources, around 75 percent of paper and paperboard mills in the United States use recovered paper in the production of new paper. The same report states that 40 percent of the mills rely only on recycled paper (Rick, 2018).

The paper recycling process involves a number of steps, including collection, transportation, sorting, processing the raw materials and finally using that raw material to produce new paper products:

Collection: Waste papers are collected from collection bins and deposited in a big recycling container along with the paper collected from other collection bins. So, all kinds of paper go into a single large container (Rick, 2018).

Transportation: All the recovered or collected paper waste then gets transported to the paper recycling plant on a collection van or truck (Rick, 2018) .

Sorting: After getting transported into recycling plants, papers are sorted into different paper categories such as cardboard, newspapers, newsprint, magazine paper, computer paper etc. as Waste paper with similar qualities are combined since they have similar amounts of fiber which can be extracted from the pulp. Then different types of papers are treated differently in the next stages of the process to produce different types of recycled paper products. Processing the paper into usable raw material is the main stage in a paper recycling process there are multiple functions in the processing phase which include the following (Rick, 2018) .

Pulp or Slurry Making: Pulping involves water and chemicals. In order to pulp the paper, machines first chop it before water and chemicals are added. Then the mixture is heated to break the paper down more quickly into paper fibers. Finally, the mixtures turn into a mushy mix, known as a slurry or pulp. There are also multiple functions in the processing phase which includes Refining, Color Stripping, and Bleaching*:* In the refining stage, the pulp is beaten to make the paper fibers swell. Beating the pulp also separates individual fibers to facilitate new paper production from the separated fibers. In case coloring is required, color stripping chemicals are added to the fibers to get rid of the dyes from the paper. When the goal is to produce white recycled paper, the pulp is bleached with oxygen, chlorine dioxide, or hydrogen peroxide to make them brighter or whiter. The pulp is then passed through a series of screens, and a centrifuge-like process to remove larger contaminants such as paper clips, staples, tape, and plastic films that were included in the recovered paper (Rick, 2018).

Paper: The pulp, which is now 99 percent water and one percent fiber at this stage, may be combined with virgin pulp to enhance its properties, and is then pumped over onto a paper machine. Pulping fibers treated through mechanically and chemically, formed into a dilute suspension, spread over a mesh surface, the water removed by suction, and the resulting pad of cellulose fibers pressed and dried to form paper. If coated paper is desired for smooth printing, a coating mixture may be applied to the paper near the end of the paper-making process (Woodard & Curran, Inc, 2005).

Generally the basic steps in the paper recycling process, they are:

- Prewashing, heat and chemical loop
- Screening (coarse and fine)
- Through-flow cleaning (or reverse cleaning)
- Forward cleaning
- Washing
- deinking (Flotation)
- Dispersion
- Bleaching

2.5.1.1. Prewashing

Gross amounts of ink, clay, and other materials are removed by prewashing, which consists of fine screening, partial dewatering, dissolved or dispersed air flotation, and/or settling. The prewashed stock is next subjected to both coarse and fine screening. The fine screens are sometimes operated under pressure (Woodard & Curran, Inc, 2005).

2.5.1.2. Screening

To remove contamination from the pulp, the pulp is forced through screens with holes of different sizes and shapes to remove contaminants such as globs of glue; if the pulp still contains any heavy contaminants such as staples, the pulp may also be spun around in huge cone-shaped cylinders. The cylinders throw the heavy contaminants out of the cone using centripetal force while light contaminants go to the center of the cone and are removed (Woodard & Curran, Inc, 2005).

2.5.1.3. Through-flow Cleaning (reverse cleaning)

This process is characterized by a counter-current washing process. In one form, the stock flows down an inclined screen with several intermediate barriers. The stock is sprayed with water at each barrier, which washes substances such as ink particles through the screen. Clean water is applied at the lowest barrier and recycled. Progressively dirtier water is applied at progressively higher barriers (Woodard & Curran, Inc, 2005).

2.5.1.4. Forward Cleaning

Heavy contaminants that pass through the through-flow and fine screening processes are the targeted pollutants for the forward cleaning process. This process operates in a multistage sequence similar to that of the through-flow process. However, the stock is much more dilute (less than 1% solids) and large amounts of water are used. After screening and cleaning de-inking will be following, which involves removing ink from the paper fibers of the pulp while sticky materials known as “stickies” such as adhesives and glue residue are also separated (Woodard & Curran, Inc, 2005)

2.5.1.5. Washing

The washing process makes use of countercurrent flow washing to remove ink from the stock that has not yet been successfully removed. Equipment includes side hill screens, gravity deckers, and dewatering screws (Woodard & Curran, Inc, 2005)

2.5.1.6. Deinking

In the process of deinking, an ink has to be detached from the paper to enable it to be collected by flotation [(Chabot, Krishnagopalan, & Abubakr, S. , 1999). Flotation is one of the principal methods used to deink printed-paper pulp. It works by collecting dispersed ink particles on air bubbles and trapping them in a froth layer. The spectrum of chemicals added to the flotation circuits includes ink particle collectors (fatty acid or alcohol ethoxy carboxylates), collector activator (calcium ions), frothing agents (nonionic surfactants), and pH regulators (NaOH or Na_2CO_3) (Borchardt & Somasundaran et al., 1994).

2.5.2. Deinking Processes

Deinking of printed-paper is done using multiple steps, involving screening cleaning washing and/or flotation. Stock is first shredded, soaked, and deinking chemicals are added. Print is decomposed into fibers. Paper waste is re-pulped via a disintegrator or pulper. The main goal is to separate ink film from fibers, which can be done based on differences in their physical properties such a specific gravity difference. Large particles (100 to 300μm) are removed mainly by screening and cleaning, while smaller particles are removed mostly by flotation or by a washing method (Moss, 1997). Often, the deinking process involves a combination of these techniques. The flotation process introduces the air bubbles into the fiber slurry, diluted to about 1% consistency. The movement of the slurry and the air bubbles force the ink to float in the form of foam. The ink foam is then collected (Carre & Galland, 2007).

Increased temperature positively influences results of flotation deinking. The flotation process takes place in a flotation cell. Flotation is designed to eliminate hydrophobic elements. Often, surfactants are used during the flotation process. During the washing process, the fibers are separated from the removed ink, physically, due to differences in particle size. Washing methods can produce whiter fibers; however, it requires large amounts of water. Therefore, the washing method is not viewed as "green" (Carre & Galland, 2007). Surfactant addition is essential in order to decrease the surface tension of aqueous slurries, which will decrease with increased concentration of surfactant (Kosswig, 2000).

After this point, the surface tension of the liquid will continue to be the same despite additional amounts of surfactant (Kosswig, 2000). An elevated temperature decreases the surface tension, which results in a reduced bubble merging. The reduction in bubble coalescence results in a higher amount of smaller bubbles. This might then increase the number of collisions among ink and air bubbles smaller air bubbles improve deinking efficiency (Beneventi, Belgacem, M. N., & Carre, B, 2006)

2.5.2.1. Flotation Surfactants

A typical flotation is a three-step process and requires hydrophobic particles. It is a separation process and will not separate hydrophilic (Gottshing & Pakarinen, 2000). First, the ink particles detach from the paper fibers. Secondly, ink particles adhere to the air bubble surface. Lastly, the froth removal takes place. The successful froth removal includes the ink particles removal from the flotation cell (Zhao, Deng, & Zhu, 2004)Depending on the dosing and surface properties, surfactants can positively and negatively influence the deinking process. This unwanted effect can cause extreme frothing and weak ink floatability [(Beneventi, et al., (2010); Zhao, Deng, & Zhu, 2004).

Surfactants used in flotation include both hydrophilic and hydrophobic groups. They can vary in their nature. The choice ranges from cationic, anionic, nonionic, and amphoteric. Though, the typical choice would be anionic fatty acid and nonionic surfactants (Zhao, Deng, & Zhu, 2004).

2.4.2.2. Dispersants

Those quantities of inks that are not removed by screening, through-flow cleaning, forward cleaning, washing, and flotation are dispersed in order to make them undetectable in the finished paper (Woodard & Curran, Inc, 2005).

There are multiple reasons for adding a surfactant into a deinking process. Some surfactants act as dispersants. Their addition facilitates the separation of the fibers and ink particles. Further, it keeps them apart through the flotation process. Also, they have the power to change the particles nature from hydrophilic to hydrophobic. Dispersants should create stable foam layer for ink removal in floatation deinking. Dispersants also give solubilizing surface chemistry to ink particles. Ink particles with such surface chemistry can negatively the desired reaction with collectors. Therefore, when it comes to flotation deinking, dispersants should be avoided or used with precaution (Zhao, Deng, & Zhu, 2004).

2.5.2.3. Collectors

The addition of collectors into the deinking process causes agglomeration of the tiny ink particles. They improve the hydrophobicity of ink particles. Collectors also provide a hydrophobic surface to agglomerated particles. Besides agglomerating the ink particles, collector also adheres to air bubbles. Collectors are included in the pulping step or before flotation. There is also option to add them in the steps. There are a variety of collectors. Including simple fatty acids collectors, more complex semi-synthetic and synthetic grades collectors can be used (Gottshing L. &., 2000).

The goal is to produce light colored products out of recycled waste. In order to achieve this goal, ink has to be removed. A deinking process achieves ink removal with the above mentioned green attempt, deinking should be as gentle as possible and should not harm the environment (Retner, 2008). Recycled pulp carries a multitude of contaminants besides ink particles; there are others that influence the recycling process and the quality of the final product such as Pressure sensitive adhesives (PSA) also called stickies, which are typical macro contaminants (Veronika, 2013).

Today, recycled fibers represent about one third of the total fibrous material used as a source for printed paper substrates. The rapid growth of printing is a reason and justification for improving the performance of deinking and recycling of packaging paper substrates.

2.5.3. Bleaching

Bleaching of the pulp is highly specific to each individual mill. Bleaching can be done in the pulpier, just after prewashing, or after flotation and dispersion. Paper can be bleached with a mix of oxygen, hydrogen, peroxide, ozone, Chlorine, chlorine dioxide, peroxides, and/or hydrosulfites (Woodard & Curran, Inc, 2005). Bleached pulp is mainly used for printing and writing grades, while unbleached pulp is used in the production of packaging grades. The bleaching chemicals are injected into the pulp and the mixture is washed with water. This process is repeated several times and generates large volumes of liquid waste. Water

Recirculation and Makeup water are inherent to each of the processes (Lennart N. , Per, Lars, Siarhei, & Audrone , 2007).

Bleaching is performed on pulp in order to obtain paper that doesn't lose strength with time, doesn't become yellow when exposed to sunlight and doesn't discolor during storage. It consists in the removal of residual lignin by adding chemicals to the pulp (it doesn't matter which process was used to produce pulp, the only constraint on chemicals use is related to the desired finished product) (Tony, 2009). The most common bleaching chemicals are chlorine, chlorine dioxide, hydrogen peroxide, oxygen, caustic and sodium hypochlorite. Chlorinated compounds have been excluded because of the concerns over dioxins, furans and chloroform. Bleaching is performed in bleaching towers, where bleaching chemicals are added to the pulp in stages. Each bleaching stage is defined by its bleaching agent, pH (acidity), temperature and duration. After each stage, the pulp may be washed with caustic to remove spent bleaching chemicals and dissolved lignin before it progresses to the next stage. After the last stage, the pulp is pumped through a series of screens and cleaners to remove any contaminants such as dirt or plastic. It is then concentrated and conveyed to storage. Spent bleaching chemicals are removed between each stage in the washers. Washer effluent is collected in tanks and either re-used in other stages as wash water or sent to wastewater treatment (Corporation, 2007) .

2.6. Properties of pulp and paper

2.6.1. Basic Pulp Properties

Brightness of Pulp

The paper brightness is mainly verbalized by pulp brightness. There are some changes in stock preparation which can alter paper brightness to some extent such as filler, sizing, whitening agent, dying etc.

Coarseness of Pulp

This is a measure of the average weight of fiber per unit length, often reported in units of mg/m. It is most conveniently measured using an optical analyzer. For fibers of a given average length, it is a measure of the cross sectional area of the fiber. For a given average diameter, it is measure of wall thickness. Coarse fibers are considered to be less conformable than fine fibers and do not bond as readily. Coarser fibers also result in fewer fibers per mass of pulp, which has a significant impact on sheet formation and light scattering potential (IVL, Tehmina, & Umarah, 2012).

Drainage Time of Pulp

The drainage time of pulp is to market pulp and/or unrefined pulp. The drainage time of pulp or freeness or slowness of pulp is modified to have some desired properties in the paper, even though here it is not discussed.

Drainage of unrefined pulp which is measured as freeness can give an indication on Fiber Length of pulp, as long fiber pulps have more freeness compared to short fiber pulps. Damage to fiber during pulping, bleaching or drying as short fibers or fines produced during pulping operation, reduces pulp freeness, 3) Refining energy required to achieve certain slowness during stock preparation. The standard procedure of measuring pulp drainage is laid out in TAPPI T221, T227, ISO 5267-1 and ISO 5267-2.

Consistency of Pulp

Consistency is the term used to describe solid content of pulp during pulp processing. For pulp and paper maker this is the most important process parameters. All equipment's are designed to handle pulp at and up to certain consistency. Pulp consistency is roughly divide in to three ranges: Low Consistency: <5%, Medium Consistency: 5-15% and High Consistency: >15%.

It is the desire of every pulp maker to keep pulp at the highest possible consistency to minimize dilution water usage and which ends up as effluent. Higher consistency also helps in reducing the bleaching chemical consumption. But there are practical limitations of handling pulp at higher consistency such as high viscosity which make pulp flow very difficult. The standard procedure of measuring pulp consistency (up to 25%) is laid out in TAPPI T240.

Moisture Content of Pulp

It is important from storage, transportation and handling point of view. Most of the market pulp are sold, stored, transported and used as air dry. The useable part of pulp is dry fiber only, so the tendency is to minimize the moisture content of pulp. Small quantity of pulp is sold as wet lap also. Wet lap pulp is not dried at source and transported at about 50% moisture content. It is feasible for short distance transportation and if pulp is to be used immediately at user end.

Extractives in Pulp

The low molecular carbohydrates indicate an extent of cellulose degradation during pulping and bleaching process, which may affect pulp strength and other properties.

Fiber Length and Diameter of Pulp

The effect of fiber diameter, wall thickness and coarseness on sheet properties is rather complex and not clearly established. These qualities primarily affect fiber flexibility. Fiber diameter may be expressed mean cross section or ratio of wall thickness to diameter, sometime termed as fiber density (IVL, Tehmina, & Umarah, 2012).

Length of fibers (arithmetic average, weighted average etc.) is one of the most important parameters of pulp. Pulp strength is directly proportional to fiber length that determines the ultimate strength of fiber network reducing lignin content increase fiber strength up to certain point and dictates its final use. A long fiber pulp is good to blend with short fiber pulp to optimize on fiber cost, strength and formation of paper. Softwood with pulps in general has longer fiber compared to hard wood pulp. Pulp made from woods grown in cold climate in general has longer fiber compared to wood grown in warmer climates (IVL, Tehmina, & Umarah, 2012).

Chemical pulps have higher fiber length compared to semi chemical pulp and mechanical pulp, when made from same wood. More fibers get damaged/shorten by mechanical action than chemical action.

Fiber length changes are small, and indeed they are probably accounted for in the arithmetic average by slight changes in fines content. Certainly no major reduction in fibre length is evident. This is perhaps surprising in view of the “conventional wisdom” that fibres become fragile as a result of recycling, and are dramatically shortened.

There are several methods to measure /report fiber length of pulp. The “fiber length of pulp by projection” is described in TAPPI T232. The “fiber length of pulp by classification” is described in TAPPI T233. "Fiber length of pulp and paper by automated optical analyze reusing polarized light' is described in TAPPI T271.

Integrity number

Integrity number of recycled pulp is a potential to estimate the strength of the pulp and used as a quality parameter for paper recycling Integrity number does not content bonding factor. Fiber material integrity is a new value associated with fiber material quality, should therefore reflect its strength potential. Although strength is not always the key requirement for products, it is always important. Only when the structure has sufficient strength can other material properties be optimized. High integrity means that the material has high strength potential and is therefore easier to make into a product of sufficient strength. When such potential changes during recycling or another process, this should be reflected in the fiber material integrity value (Janne & Elias Retulainen, 2016).

The chemical composition of the pulp must also be considered. The presence of cellulose, Hemicelluloses, or lignin fractions can reveal the origin of recycled material. Pulps (and fines) of mechanical or chemical origin have different potential for later treatments (Lehto, 2011). In addition the filler amount reduces the recycled material ’sability to bear and distribute stresses around the network because of the lower amount of fiber material and reduced bonding between it (Velho, 2002).

Pulp Yield

Pulp yield is the main concern of pulp milling industry and it is mainly govern by the pulping processes. The pulp ideally needs to be pure fiber. When used paper had recycled, fibers were obtained for paper making and called pulp.

From general pulping and repulping process, mechanical pulping provides high pulp yield, which retains almost all constituents of wood including lignin. Lignin which is second highest to cellulose, does not bond to itself or cellulose as fibers do. Therefore pulps with high yield results in weak pulp. In addition to this lignin is brown in color and to maintain high yield of bleached pulp, lignin is not removed during bleaching, but only chemically modified.

Viscosity of Pulp

Solution viscosity of a pulp gives an estimation of the average degree of polymerization of the cellulose fiber. So the viscosity indicates the relative degradation of cellulose fiber during pulping /re pulping process (Tappi230, 2013).

2.6.2. Physical Properties of paper

2.6.2.1. Basic paper Properties

Basis Weight or Grammage

The basis weight, substance or Grammage is obviously most fundamental property of paper and paperboard. The Basis weight of paper is the weight per unit area. This can be expressed as the weight in grams per square meter (GSM or g/m2), pounds per 1000 ft. or weight in Kgs or pounds per ream (500 sheets) of a specific size. Paper is sold by weight but the buyer is interested in area of paper. The basis weight is what determines, how much area the buyer gets for a given weight. Paper maker always strive to get all desired properties of paper with minimum possible basis weight (Tappi205, 2013).

The area of several sheets of the paper or paperboard is determined from linear measurements and the mass (commonly called "weight") is determined by weighing. The Grammage is calculated from the ratio of the mass to the area after conversion to metric units when necessary. Grammage of up to 200gsm are considered to be papers and from 200gsm upwards they are referred to as paperboard or low quality board. Paper that is used in offices is usually between 70gsm and 80gsm, with 80gsm being the most commonly found weight.

Some accountants and solicitors use heavier weight paper ranging from 90gsm to 120gsm for formal correspondence. Above 120gsm come various thicknesses of card with 160gsm and 200gsm being most commonly used for file dividers. Newspaper sheet ranges between 45gsm and 50gsm (Srinivasan & Puttaswamygowda, 2001)

All paper machines are designed to manufacture paper in a given basis weight range. Tighter the range, more efficient will be the machine operation. The standard procedure of measuring basis weight is laid out in TAPPI T 410, SCAN P6, and DIN53104 & ISO: BSENISO536.

Table 2.1 shows the typical Grammage values of standard paper sheet (Tappi205, 2013).

Grade	g/m^2
Newsprint	40 – 50
Paperboard	120 – 300
Bond	60 -90
Cigarette Tissue	22 – 25

Thickness

For a given basis weight, thickness determines how bulky or dense paper is. A well beaten or refined pulp, short fiber pulp such as hard wood or straw pulp, highly filled or loaded paper will show lower thickness for given basis weight. Thickness or Caliper of paper is measured with a micrometer as the perpendicular distance between two circular plane parallel surfaces under a pressure of 1 kg / cm^2. Uniform caliper is good for good roll building and subsequent printing. Variations in caliper can affect several basic properties including strength, optical and roll quality. Thickness is important in filling cards, printing papers, condenser paper, saturating papers etc (Tappi411, 1997).

Curl

Paper curl can be defined as a systematic deviation of a sheet from a flat form. It results from the release of stresses that are introduced into the sheet during manufacture and subsequent use. Paper curl has been a persistent quality issue and is increasingly important for paper grades being subjected to high speed printing, xerography and high precision converting processes (Tappi520, 2007).

There are three basic types of curl, mechanical curl, structural curl and moisture curl. Mechanical curl develops when one side of the paper is stretched beyond its elastic limits (Tappi520, 2007).

One example of this is the curl in the sheet which forms near the center of a roll. Structural curl is caused by two sidedness in the sheet that by a difference in the level of fines, fillers, fiber area density or fiber orientation through the sheet thickness. Moisture curls can develop when the paper sheet is being offset printed. One side of the sheet may pick up more moisture than the other, the higher moisture side releases the built in drying strains and the paper will curl towards the drier side (Tappi520, 2007).

Dimensional Stability

Cellulose fibers (main constituent of paper) swell in diameter from 15 to 20% from dry condition to saturation point. Since most of the fiber in paper sheet are aligned in the machine run direction, absorption and de-absorption of moisture by paper causes the change in CD dimension. Such changes in dimension may seriously affect register in printing processes and interfere with the use of such items as tabulating cards. Uneven dimensional changes cause undesirable cockling and curling. Dimensional changes in paper originate in the swelling and contraction of the individual fibers. It is impossible to be precise about the degree of this swelling because paper making fibers differ considerably in this property, and because the irregular cross section of fibers creates difficulty in defining diameter. Change that occurs in the dimensions of paper with variation in the moisture content is an important consideration in the use of paper. All papers expand with increased moisture content and contract with decreased moisture content, but the rate and extent of changes vary with different papers.

Dimensional stability of paper can be improved by avoiding fiber to absorb moisture. Well sized papers have better dimensional stability (Green , 1999).

Moisture content

Moisture control is significant economic aspect of paper making. Poor moisture control can adversely affect many paper properties (Tappi550, 2013). All strength properties are sensitive to moisture about 1% change in a sample's moisture content changes the compression strength with an average of 8%.

Formation

Formation is an indicator of how uniformly the fibers and fillers are distributed in the sheet. Formation plays an important role as most of the paper properties depend on it. A paper is as strong as its weakest point. A poorly formed sheet will have more weak and thin or thick spots. These will affect properties like caliper, opacity, strength etc. Paper formation also affects the coating capabilities and printing characteristics of the paper. A poorly formed sheet will exhibit more dot gain and a mottled appearance when printed (PaperOnWeb, 2019).

There is no standard method or unit to express formation. It is a relative or subjective evaluation. However when holding paper up to a light source, a well formed sheet appears uniform while a poorly formed sheet has clumps of fibers giving a cloudy look (PaperOnWeb, 2019).

Smoothness

It is most important parameter for printer. Smoothness is concerned with the surface contour of paper. It is the flatness of the surface under testing conditions which considers roughness, levelness, and compressibility. In most of the uses of paper, the character of the surface is of great importance. It is common to say that paper has a "smooth" or a "rough" texture. The terms "finish" and "pattern" are frequently used in describing the contour or appearance of paper surfaces. Smoothness is important for writing, where it affects the ease of travel of the pen over the paper surface. Finish is important in bag paper as it is related to the tendency of the bag to slide when stacked. Smoothness of the paper will often determine whether or not it can be successfully printed. Smoothness also gives eye appeal as a rough paper is unattractive (Tappi479, 2009).

Optical Properties (Brightness, Whiteness and Colour)

Brightness is defined as the percentage reflectance of blue light only at a wavelength of 457nm. Whiteness refers to the extent that paper diffusely reflects light of all wave lengths throughout the visible spectrum. Whiteness is an appearance term. Color is an aesthetic value and it may appear different when viewed under a different light source. Brightness is the most important measure of quality for many types of pulp. Bleaching is associated with high cost and control of brightness will reduce the cost of bleaching chemicals. The brightness parameter is used to monitor the bleaching process. Brightness together with fluorescence is used to supervise the dosage of OBA (optical brighteners) and it is the most commonly used parameter in the sales specifications of paper and paperboard products (Tappi452, 2008) .

Brightness is measured with two different standards TAPPI/GE and ISO. Though there is correlation, ISO brightness of a sample is usually lower by 1-1.5 units over GE brightness. The standards are as per TAPPI T 452. The procedural standards for the measurement of Whiteness are explained in ISO 11475 (Tappi452, 2008).

Bursting Strength

Bursting strength is the capacity of a material (such as a paper or textile) or object (such as a metal pipe) to maintain in continuity when subjected to pressure; broadly the pressure often expressed in pounds per square inch required to rupture such a material or object under rigidly controlled conditions. It is a pressure measured at which a pulp sheet will burst, used as a measure of resistance to rupture. TAPPI method T-403 is the official test used for measuring the bursting strength of papers pressure applied through a rubber diaphragm on a sample with thicknesses up to 0.6 mm and diameter 1.20 inch (30.5mm) (Anon, 1987).

Burst strength depends largely on the tensile strength of extensibility of the material/pulp sheet/ and it is also commonly known as the Mullen test (http:/papersizes.org). The standards procedure is described in TAPPI T 403.

Tensile Strength

Tensile strength of paper is the maximum strength of randomly oriented pulp fiber when formed in a sheet. It is the force required to produce a rupture in a strip of paper or paperboard, measured in MD and CD, expressed in KN/m. This tensile strength gives an indication of the maximum possible strength of pulp beaten under ideal condition. In addition to this; tensile strength is an indicative of fiber strength, fiber bonding and fiber length. Tensile strength can be used as a potential indicator of resistance to web breaking during printing or converting (Tappi541, 2010).

Tensile strength can be described by stress-strain graphs and measured by TAPPI tests T-404 and T-494. Stress-strain curves provide a fundamental engineering description of the mechanical behavior of paper when subjected to tensile stress. TAPPI method T-404 measures tensile breaking strength and elongation of paper and paperboard using a pendulum type tester, and T 494 measures tensile breaking properties of paper and paperboard using constant rate of elongation apparatus.

Tearing Resistance

Tearing resistance or strengths is a measure of how well a material can withstand the effects of tearing. More specifically it is how well a paper resists or withstands the growth of any cuts when under tension.

Tearing resistance indicates the behavior of paper in various end use situations; such as evaluating web run ability, controlling the quality of newsprint and characterizing the toughness of packaging papers where the ability to absorb shocks is essential. Fiber length and inter-fiber bonding are both important factors in tearing strength. It is measured in both MD and CD and expressed in milinewton (mN).

The most commonly used tearing test is T-414, which is often called the Elmendorf tear test, and measures the internal tearing resistance of paper rather than the edge tear strength of paper, which is described in T-470 (Anon, 1987). Internal tearing resistance is a measure of the force perpendicular to the plane of the paper necessary to tear a single sheet through as specified distance after the tear has already been started. Edge tearing strength (T-470) is a measure of the force needed to initiate a tear. The force needed to initiate a tear may be several times the force needed to propagate the tear once it is started. This is commonly known to anyone who has experienced the difficulty of opening a cellophane bag, which, once nicked, tears open easily. Those papers and other film materials that exhibit high tensile stretch or elongation to break also exhibit high edge tearing strength .High stretch makes it difficult to localize or concentrate stress in a sufficiently small area so that a tear can be initiated.

2.6.3. Recycled pulp Properties

Recycled fibers have long been known to have inferior strength properties compared to those of virgin fibers. The change in the basic fiber characteristics strength, length, swelling, and bonding potential has been assumed to be the source of reduction in strength properties (Ellis & Sedlachek, 1993). Thus, one of the most challenging aspects of recycling is to understand how to increase and control fiber bonding potential most studies have shown that the strength properties of fibers and paper are reduced upon recycling. Drying influences fiber strength, fiber swelling and bonding potential, which are the important factors to the strength of paper made from recycled fibers (Cutler, 1995).

The strength properties of recycled paper, such as tensile and bursting strengths, which are dependent on fiber bonding, are dramatically decreased with recycling. However, for strength properties of recycled paper where fiber bonding is not the main factor, such as tear strength, recycling seems to have a beneficial effect up to a certain level of recycling (McKee , 1971).

The type of wood from which the pulp is derived and the lignin content of the original pulps also appear to have different effects on the changes in recycled pulp properties .Hornification is thought to occur to a much greater degree in the low yield pulps. This involves polysaccharide hardening at the molecular level in dried pulp and possible changes in the microstructure of the recycled fibers (Atalla, 1977). These changes might also account for the altered appearance of the fibers; Microstructural changes in the recycled fibers could also change the surface free energy and thus influence the nature of water interactions on and into the fiber (Nankoh & Ohsawa, 1991).

Pulping: Waste paper may be purchased or taken from either the mill's paper machine or other mill areas. Pulp made in the hydro pulper is processed through beaters, cleaners and refiners. The recycled pulp produced can be used alone or can be blended with virgin pulp (GAPS , 2011).

Virgin pulp is comes from ecological sources like trees or plants without having been through a recycling process.Their fibres lengths are mainly what give paper its different characteristics. Virgin pulp fibres can be in length from 5mm (those from the softwood trees) to 1mm (from hardwood trees). The long fibres of the softwoods are perfect for making strong Kraft papers, compared to shorter hardwood fibres which help towards a nice smooth finish (Keenpac, 2017).

On the other hand recycled paper contains fibre from waste paper. It can often include a high proportion of 'post-consumer waste' which is paper that has already been used in its final form. Not always. The recycling process is damaging to fibres, which lose strength when they have been recycled again and again. The more times a fibre is recycled, the shorter and weaker it becomes. For the best of both, recycled fibres can be added to a virgin pulp as a 'mix', offering the benefits of virgin with the lower cost of recycled. The mix can be varied to increase or decrease the characteristics of each. Recycled papers are often slightly 'off-white' or grey or other in color depending on the raw papers being recycled a feature that's created when the print or dyes in the original paper are mixed with recyclate. Special additives can be also used to remove the dyes, and achieve a similar visual appearance (if not strength) as a virgin paper (Keenpac, 2017).

Mills that recycle paper, such as newspaper, magazines and other label paper must deink the paper. De-inking involves a specialized group of screens, cleaners, filters, presses, bleaching units and waste handling systems. Recycling usually includes provisions for removing plastic and metal bands, paper clips, staples, glue, bindings and other materials likely to be found in paper being recycled. Mills that depend on recycling must make sure equipment is kept in good operating condition and protected from foreign object damage.

Generally Characteristics of recycled pule are:

- ✓ It is fully mechanical
- ✓ It is secondary fiber

- ✓ It is unbleached
- ✓ It has strong benign capacity

There are two types of cellulose fibres :

a) Fibres (softwood)

b) Long fibres (hardwood)

In general, softwoods have slightly less cellulose and more lignin than hardwoods, due to the more simplistic structure of softwoods. The difference in wood structure affects not only the exact ratio of these components, but also their properties.

However, this fiber is not analogous to the virgin fiber from a chemical or mechanical pulping process. This fiber has already been processed into paper at least once before and exposed to a myriad of chemicals during the initial papermaking process and throughout its useful era (Adam, 2008). Fibers undergo a series of changes during the recycling process. The surface chemistry of recycled fibers is affected by the chemicals the pulp contains (Kuys & Zhu, 1997).

De-inking chemicals, residual polymer such as retention aids in the furnish and the flotation surfactants used during de-inking, and filler can all change the surface charge of the fiber.

The surface charge of the chemical additives differed greatly from those of the pulps that were analyzed. In the case of kraft fiber, which had an extremely low surface charge, the presence of inks and filler would cause a drastic increase in the observed charge of a pulp sample. The increase in the observed surface charge of recycled pulps is due to the presence of chemicals, and not to a change in the fiber itself (Rao & Kuys, 1995).

In addition to these chemical changes, the mechanical action of re pulping can damage and shorten the fibers leading to decreased fiber strength and lower sheet tensile strength finally the rewetting and drying of cellulose fiber causes hornification (Badar, 1992).

Inter fiber bonding

The most generally recognized property losses in paper recycling are those associated with inter fiber bonding, such as tensile and burst strengths. Inter fiber bonding consists primarily of hydrogen bonds between the surface carbohydrate macromolecules of neighboring fibers. The extent and magnitude of inter fiber bonding depends on the exposure of polysaccharide molecules and the surface functional groups such as hydroxyl, carbonyl, and carboxyl. It also depends on the extent of surface contact between fibers. The property that reflects the ease with which fibers are flattened and brought into contact with one another is known as fiber conformability. Surface contact may also be increased by fibrillation. Fibrillation is a disruption of the surface structure of the fiber, which produces strands or ribbons of cell wall polysaccharides when the fibers are laid down in a paper mat, this fibrinous material overlaps adjacent fibers, creating strong inter fiber bonds. Loss in inter fiber bonding is observed in fibers that have been thoroughly dried, as in the dryer section of most paper machines. The loss is attributed to collapse of polysaccharide macromolecules onto each other as a result of dehydration, resulting in strong intermolecular hydrogen bonds (James, Minor , & Rajai , 1992).

Hornification

Hornification is the term used to describe the irreversible changes that a fiber under goes as it is dried and rewet (Adam, 2008).

Effects of Hornification

Hornification causes both a loss of water retention in pulp and a decrease in the tensile strength of the resulting sheet. At the most basic level, hornification is the permanent loss of swell ability in cellulose fibers, leading to a loss of fiber flexibility. Basically, fiber flexibility and swell ability are the main contributors to the strength of inter fiber bonding. Fibers that have been dried more closely resemble their dried state after rewetting than they do their never-dried state (Bawden & R.P. Kibblewhite, 1995). The fiber wall collapses upon the initial drying and can never fully re bloat, with each of drying and rewetting, the fiber continues to collapse, although the effect is the most affected during the initial drying (Bendzalova, Pekarovicova, Kokta, & R, 1996).Hornification is traditionally measured by determining the reduction in the water retention value (WRV) of the pulp after drying, although WRV measurement cannot reveal exactly how the fiber is changed (Tze & D.J. Gardner, 2001).

The macroscopic level (density, volume, porosity, paper thickness) consists from the physical properties very important for the use of paper and paperboard. They indirectly characterize the three dimensional structure of paper A paper is a complex structure consisting mainly of a fiber network, filler pigment particles and air. Light is reflected at fiber and pigment surfaces in the surface layer and inside the paper structure. The light also penetrates into the cellulose fibers and pigments, and changes directions. Some light is absorbed, but the remainder passes into the air and is reflected and refracted again by new fibers and pigments (Pauler, 2002).

Most physical properties of paper undergo change as a result of variations in moisture content. At least six options are available to mills to enhance the strength properties of papers made from recycled fibers: mechanical treatment, blending with virgin fibers, chemical additives, fractionation, chemical treatment, and paper machine process modifications. For recycled mechanically pulped fibers, a mechanical treatment such as disk refining restores nearly all the original strength. However, unless special efforts are made to reduce the refining intensity, the strength gain may come at a sacrifice of drainage because of the generation of fines (M. R. Doshi, 1992). Soft wood pulps may also be refined to the initial strength level. However, the more the initial pulp is refined, the more difficult the restoration of initial strength with mechanical treatment alone (McKee , 1971). Although a few mills are producing 100% recycled paper, the majority are attempting to meet recycling demands by adding recycled fibers to their present virgin fiber lines. In this regard, the question is usually how much recycled fiber can be accommodated rather than how much virgin pulp is required to upgrade the recycled pulp. The latter situation is similar to the addition of chemical or chemi mechanical pulp as “reinforcement” to the ground wood in newsprint (James, Minor , & Rajai , 1992). Starch or gums or other dry strength-enhancing agents are well known and may be added to the recycled fiber furnish to compensate for the loss in original strength. Recycled fibers may be separated by screening into long and short fiber fractions. This permits more flexibility in the use of the secondary fiber stock by allowing the use of longer fibers where higher strength is required, such as in linerboard or in separate plies of multiply products (Skaar, 1984).

The press section of the paper machine assists water removal from the wet web and improves inter fiber bonding by increasing fiber-to-fiber contact. Various modifications have recently been proposed for the press section (L Wicks & T .Blis, 1986).

Fiber Shortening

An increase in fines is usually observed during the recycling operation. The fines may result from the cutting of fibers or from fibrillar debris from previously bonded paper. The amount of fines generated depends on the severity of the original papermaking process and the extent of mechanical treatment during recycling. The drying operation may contribute significantly to the generation of fines in recycling. Fines may have a beneficial effect on inter fiber bonding (M Wollerdorfer & H, 1998).

Inter fiber Bonding Enhancement

There are more than three options are available to mills to enhance the strength properties of papers made from recycled fibers: mechanical treatment, blending with virgin fibers, chemical additives, fractionation, chemical treatment, and paper machine process modifications. For recycled mechanically pulped fibers, a mechanical treatment such as disk refining restores nearly all the original strength. However, unless special efforts are made to reduce the refining intensity, the strength gain may come at a sacrifice of drainage because of the generation of fines (M. R. Doshi, 1992).

2.7. Raw material preparation

The preliminary operation, before pulping, is the preparation of raw materials. The primary purpose of raw material preparation is to make it suitable for pulping by chopping the waste paper and modify its shape in order to be used in the pulping process. To do so, the area of a pulp mill has several functions: to receive and measure the waste paper supply to the pulping process at the rate demanded by the mill; to prepare that it meets the mill's feed specifications for species, cleanliness and dimensions removal of stickes; and to collect any material rejected by the previous operations.

2.8. Environmental Benefits of Recycled Paper

Recycled paper is better for the environment than virgin paper. It helps preserve forests, because it reduces demand for wood. It conserves resources and generates less pollution during manufacturing, because the fibers have already been processed once. And it reduces solid waste, because it diverts usable paper from the waste stream. Paper recycling more importantly saves forests. By substituting used paper for trees, recycling reduces the overall intensity of forest management needed to meet a given demand for paper, and with recycling, not only are fewer trees harvested to make paper, but those trees that are harvested can be produced using methods that have less impact on the environment. Thus, recycling helps preserve the full range of values that forest ecosystems provide (Bajpai, 2014).

Every tone of recycled fiber that displaces a tone of virgin fiber results in the following reductions in usage:

- ✓ Wood, 100%
- ✓ Total energy consumption, 27%
- ✓ Wastewater, 33%
- ✓ Air particulate emissions, 28%
- ✓ Solid waste, 54%

Producing recycled paper uses much less total energy than producing virgin paper (Vest, 2000). Depending on the grade, producing recycled paper may use more or less energy in the form of fossil fuels. Virgin free sheet grades require slightly less purchased energy to produce than recycled ones, because some of their energy needs are met by burning wood-derived process waste. Virgin ground wood papers, by contrast, require more purchased energy to produce than recycled ground wood papers (Bajpai, 2014).

2.9. Economic benefits of recycling waste beer label for Ethiopia

Protection of the environment is not the only factor that encourages the recycling of waste label paper. It also offers an economic incentive for paper industry in Ethiopia which contributes a tremendous role in the paper traders or importing the pulp, the industries will save money that cost transportation of the wastes, and it creates job opportunity for many unemployed and it subsidizes in the minimizing unemployment and eradicates poverty.in addition to this the produced paper can used as packaging material and replace plastics bag (festal).

3. Materials and Methods

3.1. Raw Material collection and pulp preparation

The main raw material used during the experimental works was waste beer label paper which is collected form Heineken brewery SC, in May 2019 (Figure 3.1). In addition, waste A_4 papers also mixed. For repulping processes, 20 g waste label paper sample were measured and cut into pieces using Scissor and homogenized with blender, which equipped with special blade to reduce fiber cutting (Figure 3.2.). After 1000 ml water was added, the pulp was disintegrated on low speed for 2 minutes. The content was then transferred quantitatively into a vat using 2000 ml water as rinsing liquor, thus pulp suspension was then de-flaked for 5 minutes within the vat. The disintegrated pulp was screened by using a flat screen mesh with 250 μm slots in another vat opening for 10 minutes and sponge and Towel was also used during screening, a water head over the screen was maintained at 3 seconds and water flow was kept constant.


(a)

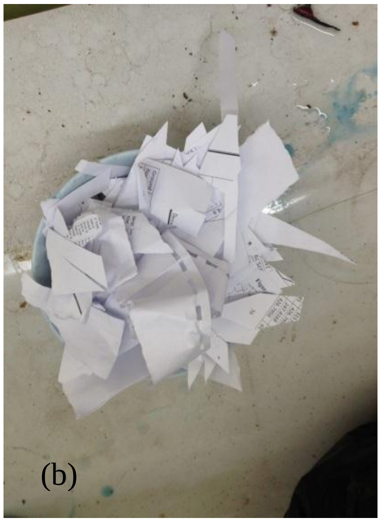
(b)

Figure 3.1: Waste beers label from Heineken beer factory (a) A_4 sized paper from AAiT (b)

Figure 3.2: Blending of the waste beer labels with blender (a) Repulped slurry (b)

3.1.1. Pulp hand Sheet Preparation

For Sheet Preparation, the blended pulp produced from optimized pulping condition was used for sheet preparation. 400 g of oven dry pulp was mixed with 23 liters water and pulp slurry with consistency (percentage of weight of dry fibrous material of pulp and water) of 1.7 % was made. The prepared pulp slurry was then added to the beating machine (Fig 3.3). Freeness (measure of dilute suspension of pulp drained) of slurry was checked out at each ten minutes beating interval. Freeness was checked by taking 130 ml of slurry from the beater (this contains 2g of moisture free fiber) and diluted to 1000 ml with distilled water and measured freeness value. When the freeness of pulp was 30 CSF (Canadian standard of freeness), 1200 ml of stock was taken from beater and diluted to 2000 ml water (0.62 % consistency) with 800 ml wash. Then it was placed to the disintegrator with 500 rpm for five minutes. Then the blade of the disintegrator was washed with 250 ml water and transferred to plastic vat and diluted with 2000 ml water to a total volume of 6250 ml and agitated well by hand. Materials from the diluted suspension was then taken and spread over the required paper sheet forming machine. Once the sheets were prepared two stage pressing was followed by applying 0.4 MPa pressure for two minutes by pressing machine (Fig .3.4). Then the stocks were removed from the press and attached to the drying plates in order to dry by oven at 100^{o}C for 30 minutes.

a b

Figure 3.3: Pulp beating machine while beating (a), Pulp slurry after beating (b)

a b

Figure .3.4: Sheet forming and pressing machine (a) Pressed blende waste beer label sheet (b)

3. 2. Morphological Characterization of Waste beer label

The Morphological analysis of recycled beer label fiber was done at Ethiopian environmental and Forest Products Utilization Research Center, Addis Ababa around Saris. In order to get representative results of fiber diameter five randomly selected samples of waste beer label pulp were taken .For fiber length determination, small slices were taken, soaked with water for four hours. The slices were then washed, and the fibre bundles were separated into individual fibers using a small mixer with a plastic end to avoid fibre breaking. The soaked fibers suspension was finally placed on a slide (standard 7.5 * 2.5cm) by means of dropper (Han, Mianowski, & Lin, 1999).

All fiber samples were viewed under a calibrated Motic electron microscope at 100X magnification; Only fiber diameter were measured because the selected raw material was used paper it was demanding to measure other physical properties of the fibers as explained in the literature review.

The waste label was repulped using a vat by taking roughly 20g of the label was disintegrated in 1000 ml of water for 4 minutes revolutions to fully mixing and produce pulp slurry of approximately 0.3% consistency. After the samples were mixed, it was again made into pulp sheets following established procedures for further processing.

3.3. RePulp Yield Determination

The slurry, then dewatered on a 250 μm-1mm mesh screen, followed by pressing by covering with towel and using sponge to 25 % solids content and wet pressed to 75 % moisture content. After the sheet pressed then it was dried by using drying chamber (oven).

Addition of A_4 size paper as mixture is due to the fact that, repulping the wasted beer label paper alone has short and threated fibers that has to be enhanced its bonding potential. When used paper (less threated, not inked no waterproofing) blended with it we got fibers suitable for paper making .Since blended waste beer are also made of many chemical compositions and not pure as virgin fibers it is unthinkable to get 100 % pulp yield. Unfortunately in the blended waste beer paper, it is less than 40 % because it seems that strength properties of recycled paper, which are dependent on fiber bonding, are dramatically decreased with recycling. We expect the loss of pulp yield due to recycling. Repulp yield expressed as percentage of the oven dry pulp and was determined by the method as per Tappi standards (Tappi, 1985).

Yield of the pulp from each experiment was calculated as:

$$\%\ yield\ of\ pulp = \frac{weight\ of\ oven\ dried\ repulp}{Weight\ of\ waste\ beer\ label\ paper\ before\ pulping} * 100 \quad \ldots\ldots 3.1$$

3.3.1. Pulp hand Sheet Characterization

Physical tests such as Grammage, Tensile index, tear index and burst index of the prepared hand sheet were performed at Ethiopian Pulp and Paper Factory located at Wonji. The physical characterization procedures are described as follow:

3.3.1.1. Grammage

Grammage is a French term used to express mass per unit area of a paper. The SI metric units, in which Grammage (mass per unit area) is expressed in grams per square meter (g/m^2).

After the test specimen has been prepared using cutting device of size 10cm by 10cm to accuracy of 0.2% and weighed. Then Grammage of paper sheet was calculated as:

$$Grammage = \frac{weight\ (g)}{Area\ (m^2)} \quad \ldots\ldots 3.2$$

Where,

G =Grammage

W = mass of test specimen, gm

A = area of test specimen, m^2

3.3.1.2 Tensile Properties

Tensile strength

This tensile strength gives an indication of the maximum possible strength of pulp or paper beaten under an ideal condition.

Schopper type tensile strength tester was used for tensile test according to the following

Procedure:

From specimens of undamaged paper 15 mm wide and 230 mm long test pieces were cut. The test piece was placed in the clamps making sure that any slack is eliminated. Any touch of the test area between the clamps with the fingers was avoided.

Calculation: Tensile strength

$$X_1 = \frac{a}{b} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad 3.3$$

Where:-

X_1 = tensile strength (kN/m)
a = maximum tensile force (N), instrument reading = kg, to change into (N) (34∗9.807)
b = initial width of the sample in (mm)
NB: - It is demanding to measure the thickness of recycled pulp since there was no virgin pulp.

Tensile index

$$X_2 = 1000 * \frac{X_1}{W} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad 3.4$$

Where:-

X_2 = tensile index (Nm/gm)

X_1 = tensile strength (KN/m)

W = mean grammage (gm/m^2)

Breaking Length

$$X_3 = \frac{a*102{,}000}{b} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad 3.5$$

Where

X_3= breaking length in meter, m

a = mean tensile strength in, KN/m

b = Grammage in, g/m^2

3.3.1.3. Tearing Properties

Tearing resistance

Tear resistance is a measure of how well a material can withstand the effects of tearing. More specifically however it is how well a material resists the growth of any cuts when under tension using L-W AB Lorentz & Wetter tearing tester.

The tearing resistance is the force required to continue the tearing of an initial cut in a single sheet of paper.

Principle of tear measurement

A test piece of superimposed sheets (normally four), with a specified pre-cut slit, is torn through a fixed distance using pendulum, which applies the tearing force by moving in a plane perpendicular to the initial plane of the test piece. The work done in tearing the test piece is measured by the loss in potential energy of the pendulum.

The average tearing force (work done divided by the total distance torn) is indicated by a scale on the pendulum or a digital display.

The tearing resistance of the paper is determined from the average tearing force and the number of sheets comprising the test piece.

$$X = \frac{a}{G} \quad \ldots 3.6$$

Where,

X = the tear index (Nm^2/kg)

G = grammage (gm/m^2)

a = tearing resistance (mN)

Tear index is the tearing resistance of a paper or the Tear factor divided by its factor. The result is expressed in millinewton square meters per gram (mNm^2/gm).

$$\textit{Tear index} = \frac{\textit{Tear factor}}{10.2} \quad \ldots\ldots 3.7$$

$$\textit{Tear factor} = \frac{\textit{Tear resistance (mN)}}{\textit{Basis weight }(gm/m^2)} \quad \ldots\ldots 3.8$$

The factor of the pendulum used for transferring the reading on the scale to the tearing resistance in mN.

NOT 1 sheet (specimen) = multiply 16(P=16)

2 sheet (specimen) = multiply 8(P=8)

4 sheet (specimen) = multiply 4(P=4)

3.3.1.4. Burst Properties

Burst strength, burst factor and burst index

The Burst strength of paper is the maximum uniformly distributed pressure, applied at the right angle to its surface that a test piece will stand under standardize conditions.

The burst index is the bursting strength divided by basis weight (grammage).

Motor driven Mullen (burst) tester was used to determine burst index according to the following procedure:

Procedure

- The test specimen used for the test was 2.5 by 2.5 inches.
- The test piece was clamped in the tester tightly.
- The maximum reading pointer was set to zero position.
- The pump motor was started and the pumping system was engaged and then the test piece was waited to burst.
- Finally the maximum reading pointer was read.

Instrument reading was in kg/cm^2 and to change to SI unit of bursting strength it was multiplied by 98.07.

Burst factor (Tappi Standard (Tappi205, 2013)

This factor, which has been called the bursting area, is equivalent to the number of square meters of paper, the weight of which, if applied to each square centimeter of the test sheet clamped in the instrument walled cause a burst.

$$\textbf{Burst factor} = \frac{\textbf{Bursting strength } (kg/cm^2)}{\textbf{Basis weight } (gm/m^2)} * 1000 \quad \ldots\ldots\ldots 3.9$$

Burst index: - Bursting strength divided by basis weight.

$$X = \frac{a}{W} \quad \ldots\ldots\ldots 3.10$$

Where:-

X = Burst index (Kpa m^2/Kg)

a = Burst strength in Kpa

W = Basis weight (gm/m^2)

Repulping experiments were done with the help of a three factorial statistical design. The weight of variables on repulping was monitored. The first set of experiments was performed using Heineken's wasted beer labels (100 %) then , merged with 50 % and 25 % used A_4 sized paper which was found from students of AAiT that had been used for assignment purpose.

In three experiments, the repulping pH was adjusted to pH= 9, which is commonly used within the paper recycling industry.

3.4. Experimental design

3.4.1 Studied factors

The first task before conducting experiments was the selection of potential parameters that needs to be varied. Therefore the three proposed main factors selected for this study were the drying temperature, drying time and mixing ratio of used paper that advanced to increase the bonding potential of shorted fibers of the beer label. The levels of the selected factors were determined from different previous researches as discussed above in the literature review.

Effects of the following experimental factors were thus studied:

I. Mixing ratio of used A_4 sized paper (%)
II. Drying temperature (^{0}C) and
III. Drying time t(min)

A total of 17 experimental runs were carried out according to the box Behnken design (BBD). Box Behnken design is the commonly used experimental design model for three level three-factor experiments and always has three levels for each factor and is purpose-built to fit a quadratic model. The box Behnken design does not have runs at the extreme combinations of all the factors but compensates by having better prediction precision in the center of the factor space. While a run or two can be botched in these designs the accuracy of the observations in the remaining runs is critical to the dependability of the model.. Each of the three factors had shown below in the table 3.1

Table 3.1 Experimental Factors and Levels of independent variables

Factor	Name	Units	Minimum	Mean	Maximum
A	Mixing Ratio	%	0	25	50
B	Drying Temperature	^{0}c	100	110	120
C	Drying Time	minute	60	90	120

This design of the experiment would be helpful to differentiate the significance of the interaction factors.

3.4.2. Selected Type of Experimental Design and Analysis

The repulp of waste beer label and identifying paper parameters was studied with statistical experimental design with the help of DESIGN EXPERT 11.1.0.1 statistical software using a box Behnken design (BBD) to evaluate the effects of the process variables. This method can optimize the effective parameters operating condition for preparation of the samples with a minimum number of experiments. It also helps to analyze the interaction effect between those parameters (Hawkes, 2017). In this inquiry, a three-variable box Behnken design for RSM was used to develop a statistical model for the designation of recycling of waste beer label paper. Three different levels were considered mixing with use paper (0%, 25% and 50%), drying temperature (100°C, 110°C, and 120°C), and drying time (60 minute, 90minute and 120minute). Significance within and between extractions was set from analysis of variance (ANOVA) at P value ≤ 0.05.

RSM was used to optimize the quality of pulp from waste beer label paper. A box Behnken design was used for the process variables with three factors at three levels with 17 runs, as it shown in the table (3.2). The responses function (N) was partitioned into quadratic and interactive components. Experimental data were fitted to the second-order regression equation:

$$N=ß_{0} + ß_{11}X_{11}2 + ß_{22}X_{22}^{2} + ß33X_{3}^{2} + \ldots\ldots\ldots\ldots \quad (3.11)$$

Where $ß_0$ is the intercept; $ß_{11}$ $ß_{22}$ and $ß_{33}$ are squared coefficients; and β_{12}, β_{13}, β_{23} are interaction coefficients are number of replicate at the center point.

The model adequacies were checked in terms of the values of R^2 and adjusted R^2. ANOVA was employed to determine the significance of the models.

According to the range of each variable, the independent variables are Minimum, Mean and Maximum. Therefore, response surface methodology using box Behnken design (BBD) design method was used to optimize the maximum repulp yield and evaluate the other at the maximum of the repulp yield. The optimum values of the variables tested was obtained by numerical optimization based on the criterion of desirability.

RSM approach enabled the analyses of influences from factors' interaction in addition to main effects (Montgomery, 2002) .Not only that but it also helped to further quantify the relationships between one or more measured responses and the vital input factors.

The experimental design and analysis of data, as well as the regression computations to statistically fit the response and factors' into a model made use of the software package Design EXPERT 11.1.0.1.

The effects of mixing ration, drying temperature, and drying time on the percentage of repulp yield from the experiment runs were thus studied.

Table 3.2 Samples Prepared under Different Operating Conditions

		Factor 1	Factor 2	Factor 3
Std	Run	A:Mixing Ratio	B:Temperature	C:TimeC
		(%)	(^{0}c)	(minute)
1	12	0	100	90
2	4	50	100	90
3	10	0	120	90
4	16	50	120	90
5	17	0	110	60
6	5	50	110	60
7	8	0	110	120
8	9	50	110	120
9	14	25	100	60
10	13	25	120	60
11	1	25	100	120
12	15	25	120	120
13	11	25	110	90
14	2	25	110	90
15	7	25	110	90
16	3	25	110	90
17	6	25	110	90

4. Results and Discussions

4.1. Characterization of recycled pulps

The results obtained from analyses that were used to characterize the physical and chemical properties of wastes beer label paper and determining effect of parameters such as time, temperature and waste paper classification (ratio) on papers sheet product were evaluated and the results fairly agree with the dissection of literature review.

The properties of recycled pulps were evaluated after a series of treatments designed to improve the pulp characteristic fiber diameters, fiber length, and strength**,** swelling, and bonding potential of the pulps that agreed with a result of literature.

4.2. Morphological characteristics

Morphological characterization is important method to determine, fiber length, fiber diameter, lumen width and cell wall thickness. In the present study, fiber length was found to be 1.09mm. In previous researches by Gedefaw, this parameter was reported 1.21 mm (Gedefaw, 2015). Gebeyehu et al. also found the lingth of the fiber 0.83. As we see, our resulat is in good agreement which reported values.

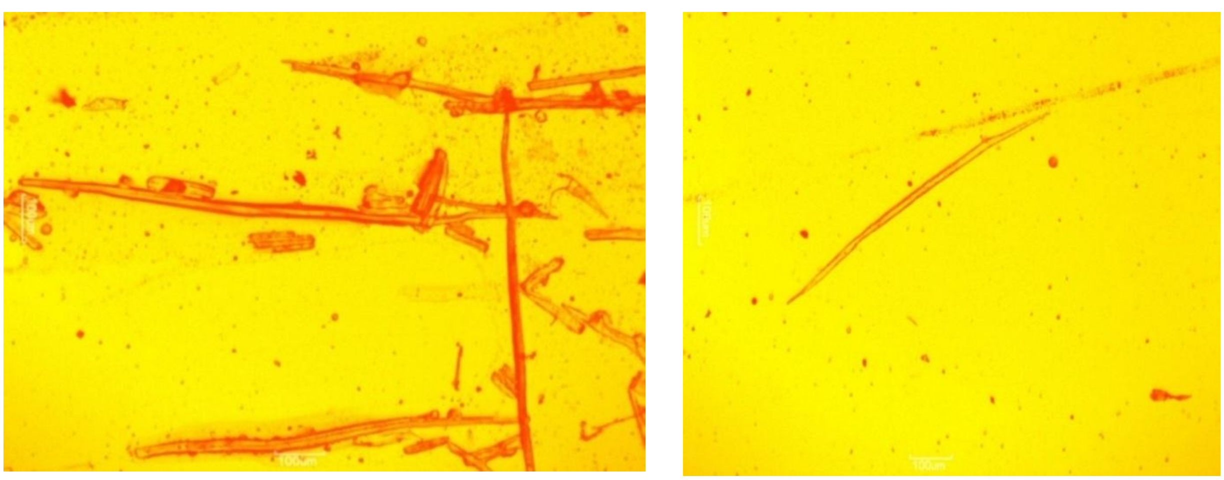

Figure 4.1: Wasted beer label fiber images obtained from Motic microscope fiber length

4.3. Pulping Results

4.3.1. Yield

High repulp yield showed fewer changes to boning potential in comparison to the low repulp yield. Hornification is thought to occur to a much greater degree in the low yield pulps. This involves hardening at the molecular level in dried pulp and possible changes in the structure of the recycled fibers.

The amount of repulped produced at different operating conditions is provided in the table below. The experiments were done with two replications and the result is given as percent yield.

Table 4.1: Percentage Yield of the Repulpe

		Factor 1	Factor 2	Factor 3	Response 1
Std	Run	A:Mixing Ratio	B:drying Temperature	C:drying Time	RePulp Yield
		(%)	(^{0}c)	(minute)	%
1	12	0	100	120	27.5
2	4	50	100	90	35
3	10	0	120	90	29
4	16	50	120	90	36
5	17	0	110	60	25
6	5	50	110	60	37.2
7	8	0	110	120	28
8	9	50	110	120	33
9	14	25	100	60	27.4
10	13	25	120	60	25.3
11	1	25	100	120	27.2
12	15	25	120	120	35
13	11	25	110	90	25.1
14	2	25	110	90	33
15	7	25	110	90	28.2
16	3	25	110	90	28
17	6	25	110	90	26.11

The effect of mixing ratio, drying temperature and drying time on repulp yield was evaluated for best repulping conditions. From the above table the maximum repulp yield (37.2%) was obtained when 50 % of used A_4 sized paper mixed with beer label paper at 110^{0}C and for 60 minutes. The second maximum re pulp yield (36 %) was obtained when 50% of used A_4 sized paper mixed with beer label paper 120^{0}C and for 90 minutes. On the other hand, the minimum repulp yield (25%) was obtained when 0 % (only beer label paper) at 110^{0}C and for 60 minutes. This showed repulping process was highly affected by mixing ratio and drying time that recycled wasted beer label fibres tend to be shortened or damaged micro-fibrils on the surface of fibres tend to be collapsed and resulting to weaker inter-fibre bonding and consequently mixing with used paper fibres to overcome strength of resulted paper (Scallan & Tigerstrom , 1992).

4.4 Effect of Processing Conditions on the RePulped Yield

The mixing ratio and drying time significantly influenced the repulp yields by interacting (interaction effects). Drying temperature, however, had the insignificant effect on the pulp yield.

4.4.1. Statistical Analysis of the Experimental Results

4.4.1.1. Analysis of variance (ANOVA)

The analysis of variance of the quadratic regression model was a significant model, from evident of Fisher's "F" test with a very low probability value [(P-model> F) < 0.0001]. From Table 4-2 it was observed that the values of "Prob> F" less than 0.0500 indicate model terms were significant. In this case A, C, AC, A^2 was significant model terms. Values greater than 0.1000 indicate the model terms were not significant. This indicates that mixing ratio, drying temperatures, drying time, the interaction between mixing ratio and drying temperatures, interaction between mixing ratio drying time affects the repulp yield.

Table 4.2 Analysis of variance for Response Surface ANOVA for Quadratic model

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	451.54	9	50.17	70.58	< 0.0001	significant
A-Mixing Ratio	336.70	1	336.70	473.70	< 0.0001	
B-drying Temperature	5.12	1	5.12	7.20	0.0314	
C-drying Time	15.40	1	15.40	21.67	0.0023	
AB	1.82	1	1.82	2.56	0.0154	
AC	2.56	1	2.56	3.60	0.0995	
BC	0.5625	1	0.5625	0.7914	0.0403	
A^2	55.02	1	55.02	77.41	< 0.0001	
B^2	21.13	1	21.13	29.72	0.0010	
C^2	5.71	1	5.71	8.04	0.0252	
Residual	4.98	7	0.7108			
Lack of Fit	0.2275	3	0.0758	0.0639	0.9762	not significant
Pure Error	4.75	4	1.19			
Cor Total	456.51	16				

The Model F-value of 38.16 implies the model is significant. There is only a 0.01% chance that an F-value this large could occur due to noise. P-values less than 0.0500 indicate model terms are significant. In this case A, C, AC, A^2 are significant model terms. Values greater than 0.1000 indicate the model terms are not significant. If there are many insignificant model terms (not counting those required to support hierarchy), model reduction may improve your model. The Lack of Fit F-value of 0.60 implies the Lack of Fit is not significant relative to the pure error. There is a 64.78% chance that a Lack of Fit F-value this large could occur due to noise. Nonsignificant lack of fit is good that we want the model to fit. The following second order polynomial model was derived to explain the repulp yield.

Final equation in Terms of Coded Factors:

$$\textit{Repulp yield} = +0.0500\times AB-1.8AC+0.8000\times BC+6.32A^{2}-0.2085B2-0.8335\times C^{2} \ldots\ldots \quad (4.1)$$

The equation (4.1) in terms of coded factors can be used to make predictions about the response for given levels of factor. By default, the maximum levels of the factors are coded as +1 and the minimum levels are coded as -1. The coded equation is useful for identifying the relative impact of the factors by comparing the factor coefficients. From the regression model equation developed in terms of coded factors, the response repulp yield of waste beer label paper was affected by interaction quadratic terms (AB, AC, BC). On the basis of the coefficient in the equation, it was evident that the response repulp yield increases with an increase in the mixing ratio (A), insignificantly increase with drying temperature (B) which have positive linear effect on yield of repulp then mixing ratio (A), again has a more substantial linear effect on repulp yield compare to drying time. Interaction between mixing ratio and drying temperature (AB) and drying temperature and drying time (BC) has a positive effect on repulp yield. While interaction of mixing ratio of the pulp and drying time of the pulp (AC), has a negative quadratic effect on repulp yield.

Final equation in terms of actual factors:

$$\textit{Repulp yield} = +0.000200\times \textit{Mixing Ratio} \times \textit{Temperature}-0.001567\times \textit{Mixing Ratio}\times \textit{Time}+0.002667\times \textit{Temperature} \times \textit{Time}+0.010106\times \textit{Mixing Ratio}^{2}0.002085\times \textit{Temperature}^{2}-0.000926\times \textit{Time}^{2}\ldots\ldots (4.2)$$

The equation (4.2) in terms of actual factors can be used to make predictions about the response for given levels of each factor. Here, the levels should be specified in the original units for each factor. This equation should not be used to determine the relative impact of each factor because the coefficients are scaled to accommodate the units of each factor and the intercept is not at the center of the design space.

4.4.1.2. Model Adequacy Check

Skimming with the table 4.3The Predicted R^2 of all the parameters in reasonable agreement with their Adjusted R^2; i.e. the difference betweenR^2 and Adjusted $R^2$is less than 0.2. Table 4.3

Table 4.3 Models Fit Summery Statistics

Std. Dev.	0.9167	R-Squared	0.9800
Mean	28.42	Adjusted R-Squared	0.9543
C.V. %	3.23	Predicted R-Squared	0.8992
		Adeq Precision	20.3562

The Predicted R^2 of 0.8992 is in reasonable agreement with the Adjusted R^2 of 0.9543; i.e. the difference is less than 0.2.Adeq Precision measures the signal to noise ratio. A ratio greater than 4 is desirable. A ratio of 20.356 indicates an adequate signal. This model can be used to navigate the design space. This shows the ratio of all parameters is greater than four indicates an adequate signal. The regression coefficient (R^2) quantitatively evaluates the correlation between the experimental data and the predicted responses. Results of R^2= 0.9800 and Adj.R^2= 0.9543from (Table 4-3) obtained explicates that the predicted values were found to be in good agreement with experimental values. Since the R^2 value was closer to 1.0 it indicates that the regression line perfectly fits the data. The model's goodness of fit was checked by regression coefficient (R^2). In this case, the value of the coefficient (R^2=0.9800) from Table 4.3 indicated that only 0.9 % of the total variance was not explained by the developed regression model. The adjusted determination coefficient (Adj.R^2=0.9543) was also satisfactory for confirming the significance of the model. Pred. R-Squared indicating that the model will probably explain a percentage (about 95 %) of the variability in new data.

The model was tested for adequacy by analysis of variance. The regression model was found to be highly significant with the correlation coefficients of determination of R -Squared, adjusted R-Squared and predicted R-Squared having a value of 0.9800, 0.9543and 0.8992 respectively. The quality of the model developed could be evaluated from their coefficients of correlation and the value of R-squared for the developed correlation is 0.9800. It implies that 98.00 % of the total variation in the percentage of conversion is attributed to the experimental variables studied.

The graph of the predicted values obtained using the developed correlation versus actual values is shown in Figure 4.2 the results in Figure demonstrate that the regression model equation provided accurate description of the experimental data, in which all the points are almost close to the line of perfect fit. This result indicates that it was successful in capturing the correlation between the three variables to the repulp yield. The adequacy of the model was further checked with ANOVA, based on 89 % confidence level, F-value is a test for comparing model variance with residual (error) variance. If the variances are close to be the same, the ratio will be close to one and it is likely that any of the factors have a significant effect on the response with the P-value less than 0.05. It was calculated by model mean square divided by residual mean square. The effectiveness of the model could also be measured so as to assure its approximation to the true value. Thus, regression coefficient, R^2, could be used for checking its adequacy. The regression value is between 0 and 1, and as it approaches to 1 it fits well to the experimental data otherwise it indicates failure of approximation. In this case, R^2, 0.9800 was obtained which was close to one and the value Adj.R^2 was 0.9543.and it is in a reasonable agreement with R^2.

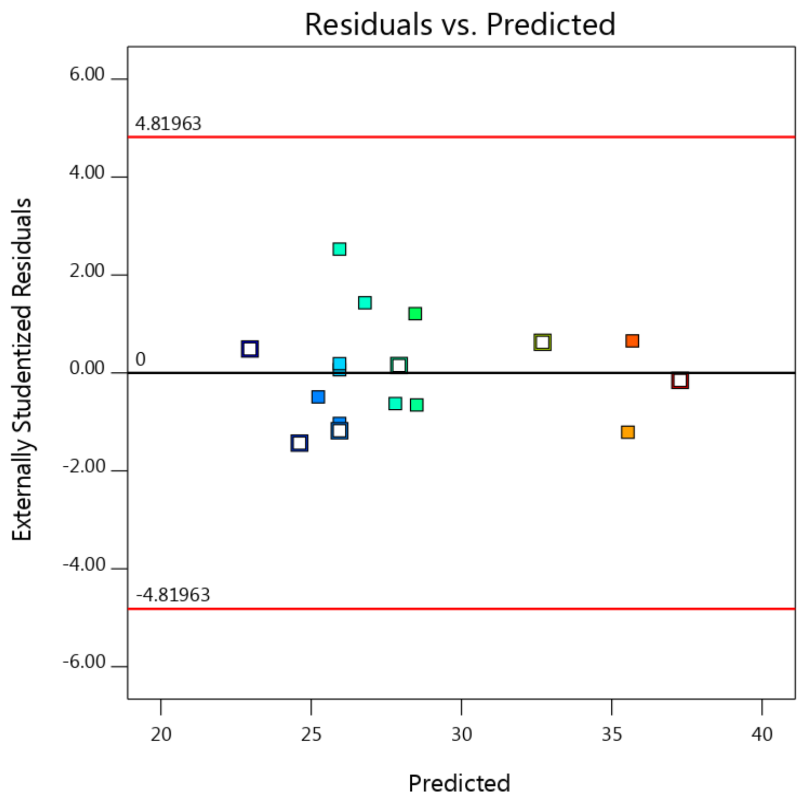

Figure 4.2: Residuals vs. Predicted response of repulp yield.

A diagnostic plot of the residuals versus predicted response values tests the assumption of constant variance. As shown from Fig 4.2, if the model was correct and the assumptions were satisfied, the residuals should be structure less; in particular, they should be unrelated to any other variable including the predicted response. The plot shows random scatter which justifying no need for an alteration to minimize personal error.

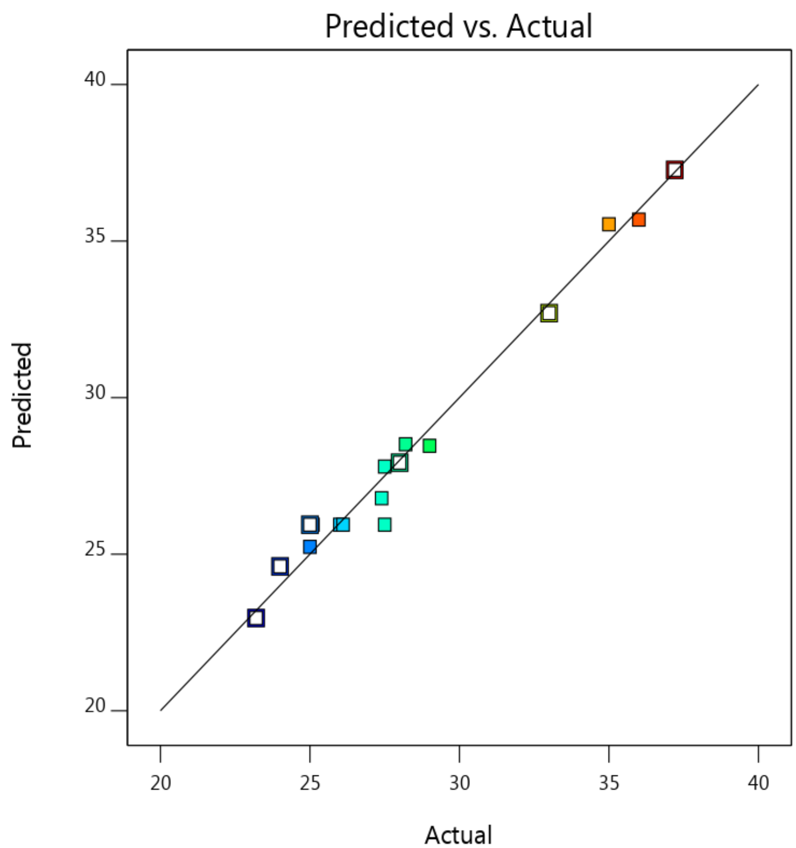

Figure 4.3: Predicted vs. Actual response of repulp yield.

In the above figure (fig 4.3) shown the predicted versus actual value of repulp yield of waste beer label paper how precisely the model modeled. The points show how the predicted value and actual values of each run approach the straight line. The straight line shows how the predicted and actual values were closer to each other. When the point was above the straight line predicted value was greater than the actual value and the reverse was also true.

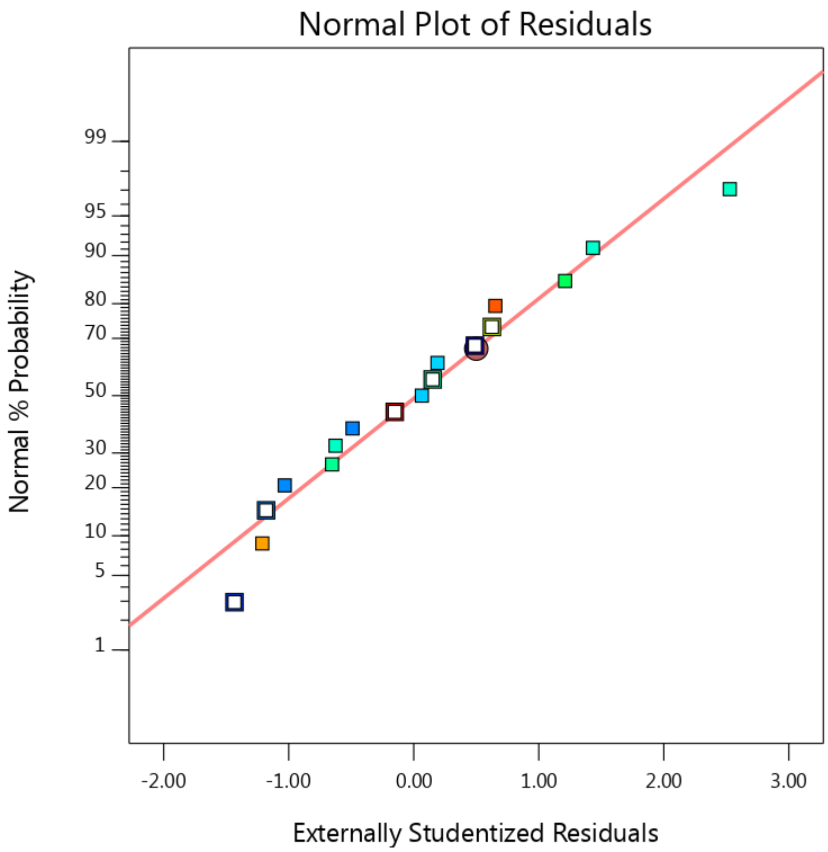

Figure 4.4: Normal plots of Residuals

From the plot (Fig 4.4) the normal probability plot indicates that the residuals following by the normal % probability distribution, in the case of this experimental data the points in the plot shows fitted to the straight line in the figure, this shows that the linear model satisfies the assumptions analysis of variance (ANOVA) and no deviation of variance i.e. the error distribution was approximately normal.

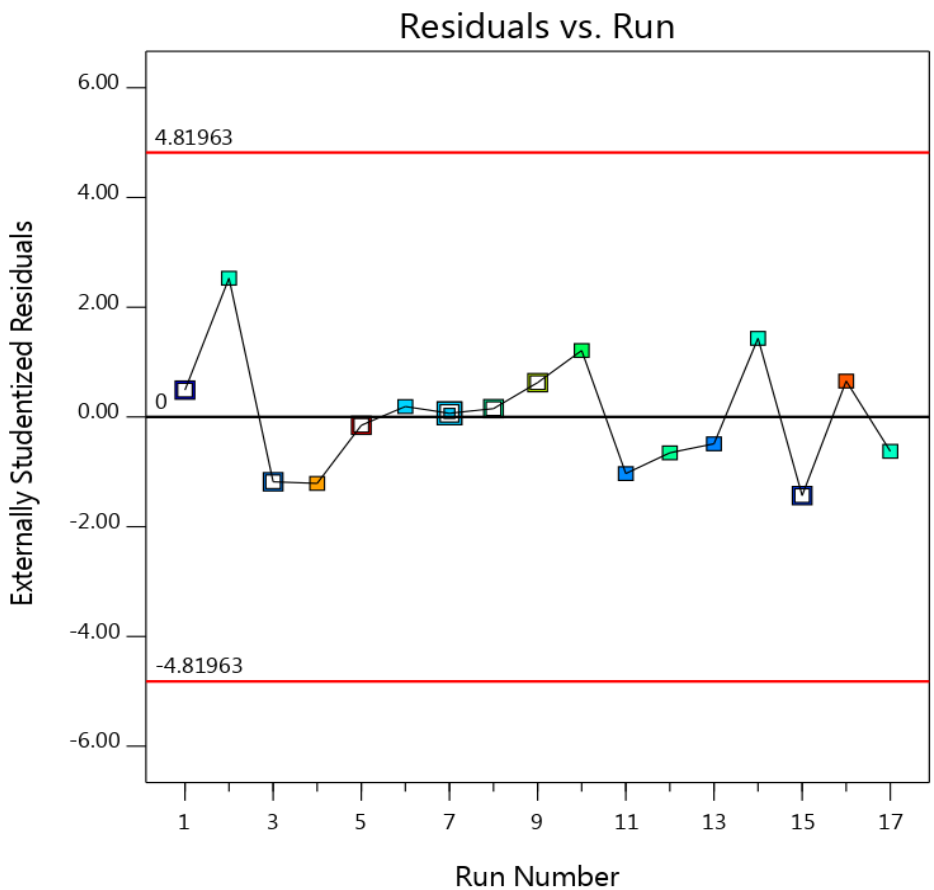

Figure 4.5: Residuals vs. Run

Fig 4.5 shows the plot of residuals versus the experimental run order. It shows that all the data points lie within the limits (± 2). As one can easily notice, the plot showed a random scatter and no more blocking or any other solutions are needed

4.5. The interaction effect of parameters variables on the repulp yield

The interaction response was also significantly affected by two interactive variables at fixed third variable. Three dimensional (3D) response surface plots (plotted in order to understand the interaction between the variables and the optimum level of each variable) were generated to determine the optimum levels of the variables that were investigated in this study. The plots were generated by keeping one variable constant at the center point and varying the others within the experimental range. The resulting response surfaces showed the effect of mixing ratio, drying temperature and drying time on repulp of waste beer label paper. The significance of the interaction between the corresponding variables was indicated by saddle nature of the contour plots. An interaction occurs when the response was different depending on the setting of two factors. Plots make it easy to interpret two factors interact. They would appear with two non-parallel lines, indicating that the effect of one factor depends on the level of other. If the plotted points fall outside of the range, the differences are unlikely to be caused by error alone and can be attributed to the factor. Therefore, in this study three interaction factors were analyzed by the model equation.

AB-mixing ratio and drying temperature

AC- mixing ratio and drying time

BC – drying temperature and drying time

Among these three interaction factors interaction of mixing ratio and drying temperature and (AB) was the most significant factor for repulp yield of waste beer label paper, because it has highly influenced repulping yield than the rest.

Therefore, the interaction factors with positive sign have positive effect on yield of repulp (as interaction factors increase yield of re pulp also increase that is best for making paper). Whereas, interaction factors with negative signs have a negative effect on repulp yield (as the interaction factors increase yield decrease that it has to be controlled not to affect the quality paper making).

4.5.1. Interactive effect of mixing ratio and drying temperature on repulp yield

The interaction effect of mixing ratio and drying temperature on repulp yield at fixed value of drying time was the most significant factor for the repulping process.

From the figure below the variation of one factor has a significant influence on the other factor. It was shown that the repulp yield of waste beer label paper had affected by the interaction of the mixing ratio and drying temperature since the lines in the plot were intermingled. It indicates that the repulp yield rises from 25 % to 37.2 % as the mixing ratio rose from 0 % to 50 % than varying the temperature from 100 ^{0}C to 120 ^{0}C with fixed drying time. The figure implies that initially mixing ratio of the paper (waste beer label paper) with used A_4 paper was zero i.e waste beer label merely was repulped and it had lower repulp yield this implied that the material beer label paper has a short fibers with lower bonding potential that need blending with moderately longer fiber in this study mixed it with used A_4 paper (longer fiber) then, when mixing ratio increases the repulp yield also increased dramatically In addition cellulose microfibrils become attached when the fiber de-wet. Therefore, the repulped yield was highly dominated by mixing ratio with interaction effect of temperature.

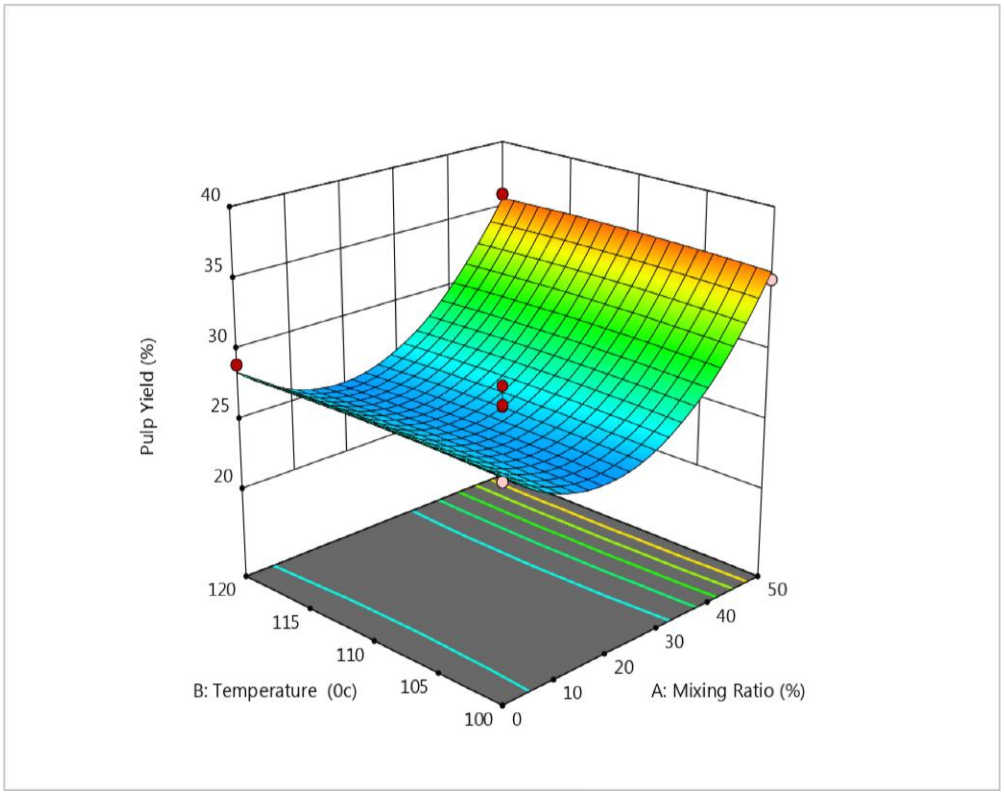

Figure 4-6: 3D Plot showing interactive effect of mixing ratio and drying temperature on repulp yield of waste Beer label paper at the center point

4.5.2. Interactive effect of mixing ratio and drying time on repulp yield

The interaction effect Mixing ratio and drying time on repulp yield at fixed value of drying temperature. From figure below, it was shown that the repulp yield of waste beer paper was partially affected by the interaction of mixing ratio and drying time since the lines in the plot were moderately interacted. This figure indicates that the repulp yield had good yield of 27.5% at constant drying temperature as the drying time rises from 60 minute to120 minute. Here there was a decreasing of the yield due to the drying time increased, the imbibed water starts to evaporate and the fibre shrinks. In this phase, movable units such as separated microfibrils molecules align themselves partly to each other (K & Giertz., 1965)

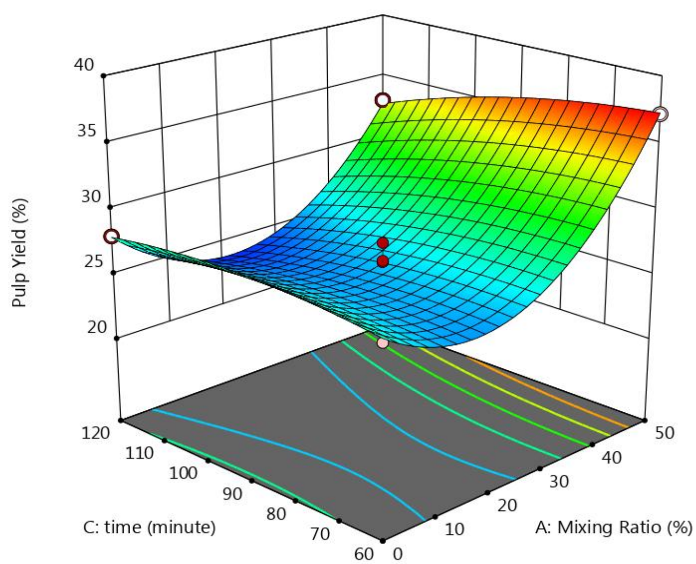

Figure 4.7: 3D Plot showing interactive effect of mixing ratio and drying time on repulp yield of waste Beer label paper at the center point

4.5.3. Interactive effect of drying temperature and drying time on repulp yield

Fig e 4.8 shows the interaction effect of drying temperature and drying time on the repulp yield at fixed value of mixed ratio (25%) at the center point. From this figure it was shown that the repulp yield of waste beer label paper was affected by the interaction of drying time and drying temperature as drying temperature with respect to drying time increased. since the lines in the plot resulted in decreasing of repulp yield and the interaction indicates that the re pulp yield reduced from 27.3 % to 25.1% at constant mixing ratio as the drying temperature from 110^0Cto120^0C and drying time goes from 90minute to120 minute at fixe value of mixed ratio (25%) i.e. as the drying time increased with respect to drying temperature, it had affect the strength of the pulp. The effects of drying are presumed to be the main factors in reducing the strength properties of recycled blended waste beers label fibers. Drying influences fiber strength, fiber swelling and bonding potential, which are the important factors to the strength of paper made from recycled fibers (Ellis & Sedlachek, 1993).The 3D response surface of the effect of the interaction of mixing ratio, drying temperature and drying time with the response of repulping yield are also discussed below

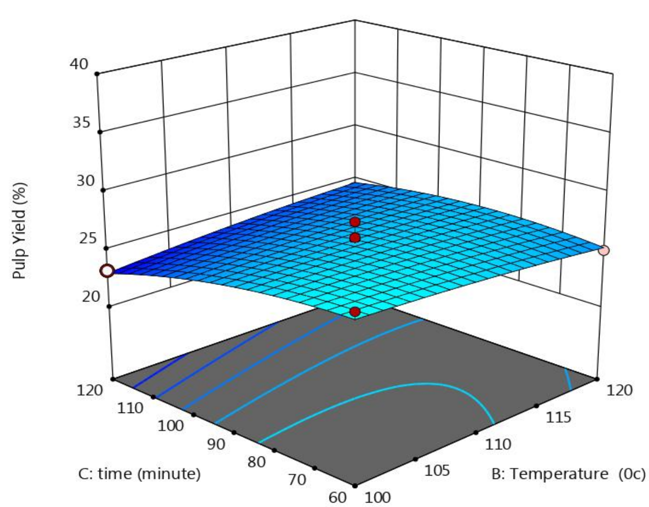

Figure 4.8:3D Plot showing interactive effect drying temperature and drying time on re pulp yield of waste Beer label paper at the center point

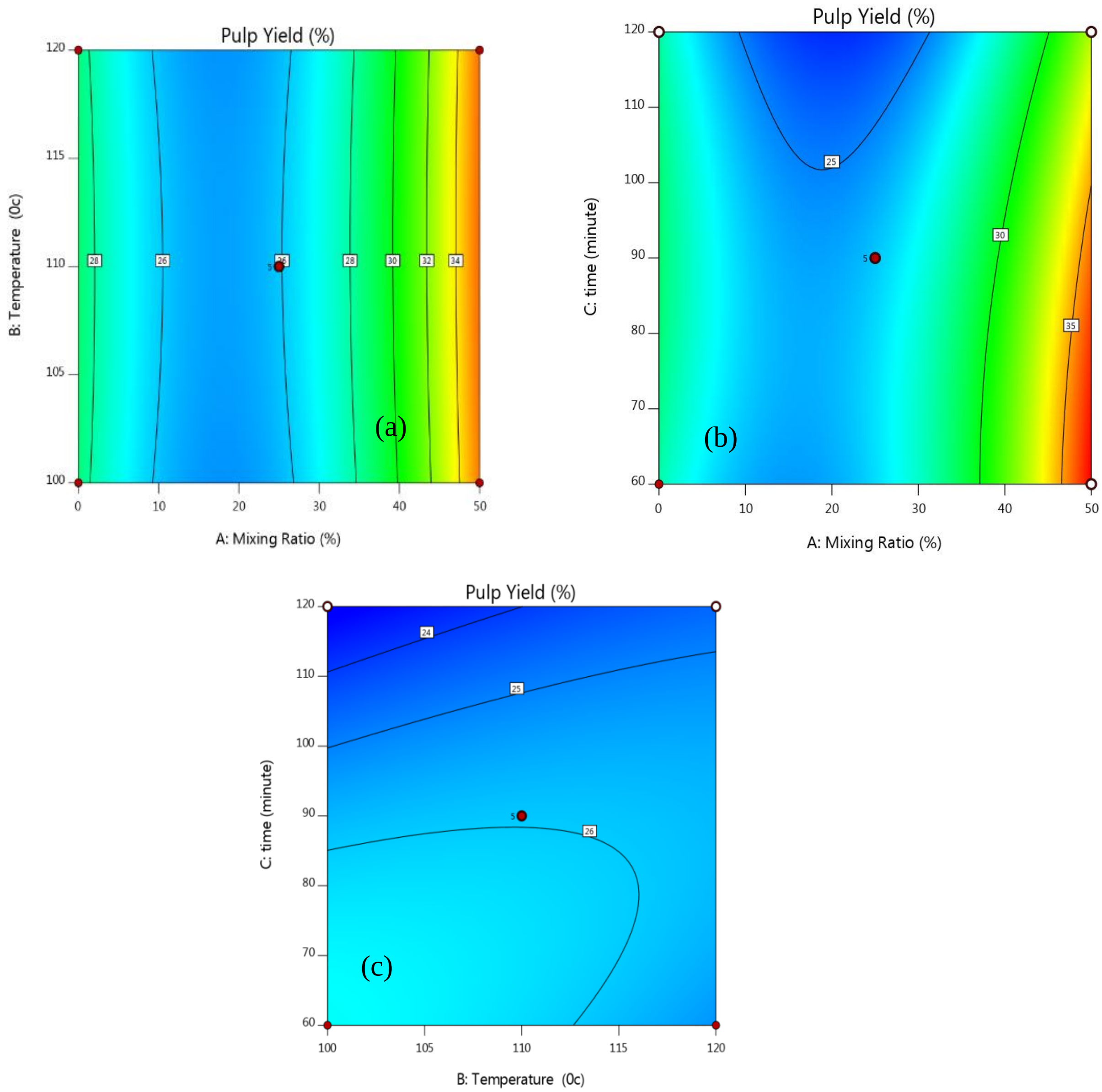

Figure 4.9: Contour plots showing repulp yield with mixing ratio, drying temperature and drying time

Figure 4.9 (a) represents the response surface of contour plots as a function of mixing ratio and drying Temperature, while the drying time was kept constant. The yield of pulp increased from 25 % to 37.2% with mixing ratio 0 %to 50 % and drying temperature from100^{o}C to 120^{o}C.However, upon increasing the mixing ratio beyond 25% and drying temperature 105 ^{o}C there was decline of the repulp yield of beer label paper from 27.2 %to 25.1%, because the raw material waste beer label paper had short fiber that it decreased the repulped yield but after a while mixed with wasted A_4 paper it started to strength the bonding potential of the pulp. There is color change on the graph and the response variable is decreasing at a null mixing ratio (from green to blue) and then it increased from blue color to red as mixing ratio increased. The graph suggests that operating at the mixing ratio where the response variable shows maximum amount (25.1 %) than in blue color (27.5 %). Operating in the red region is good to have high amount of repulp yield (37.2%).

Figure 4.9 (b) represents the response surface of contour plots developed as a function of mixing ratio and drying time, while the drying temperature was kept constant at 109^{0}C. The yield of the repulp increase from 25 % to 35.29 % with rising drying time, from 60 minute to120 minute but the effect drying time highly influenced by the mixing ratio from 0% to 50% and it fluctuates at the begging since the yield decreased from 27.5 % to 25% with increasing drying time at constant drying temperature .There is color change on the graph and the response variable is increasing from 25% to 35 % at constant drying temperature (110^{0}C) and rise in drying time from 90 minute to 120 minute.

Figure 4.9 (c) represents the response surface of contour plots developed as a function of drying temperature and drying time, while the mixing ratio was kept constant at 25%. The yield of the repulp decrease from 27.5 % to 25% with rising drying time, from 60 minute to120 minute but the effect drying temperature highly influenced the re pulp yield from 100^{0}C to 120 ^{0}C and it has less interaction effect at the begging since the yield decreased insignificantly .There is color change on the graph and the response variable is decreasing from 27.5 % to 25% at constant mixing ratio (25%) and rise in drying time from 90 minute to 120 minute.

4.6. Numerical optimization

According to the Box–Behnken design, combined with the numerical optimization technique, the optimal condition to obtain maximal repulp percentage was calculated by Derringer's desired function methodology. Therefore, mixing ratio, drying temperature and drying time were set within the studied range as shown table 4.4. The optimum values of the influencing factors for maximum repulp percentage under these circumstances are mixing ration 50 %, drying temperature 120 ^oC and drying time 120 minutes which gives 35.79 percentage of repulp at 0.884 desirability (Figure 4.10). The design expert under numerical optimization gave 72 different optimization solutions (appendix C_2).The experiments were performed at optimal values in triplicates, and the results were compared with the predicted values from the model equation. The average value of three replicate of repulp percentage under the optimum condition was obtained 37.2. The good correlation between the predicted values and the experimental values indicates that the derived Box–Behnken combined desirability method could be effectively applied to optimize the repulp processes. Furthermore, the coresponding paper paramters were investigated and the resulats were found to be 66.3 Nm/g, 6.26 $mNm^{2/}g$ and 5.42 kN/g for tensile index,tear index and brust index,respectively.

Table 4-4 Constraints Applied for Optimization

Name	Goal	Lower Limit	Upper Limit
A:Mixing Ratio	is in range	0	50
B:drying Temperature	is in range	100	120
C:drying Time	is in range	60	120
Repulp Yield	maximize	25	37.2

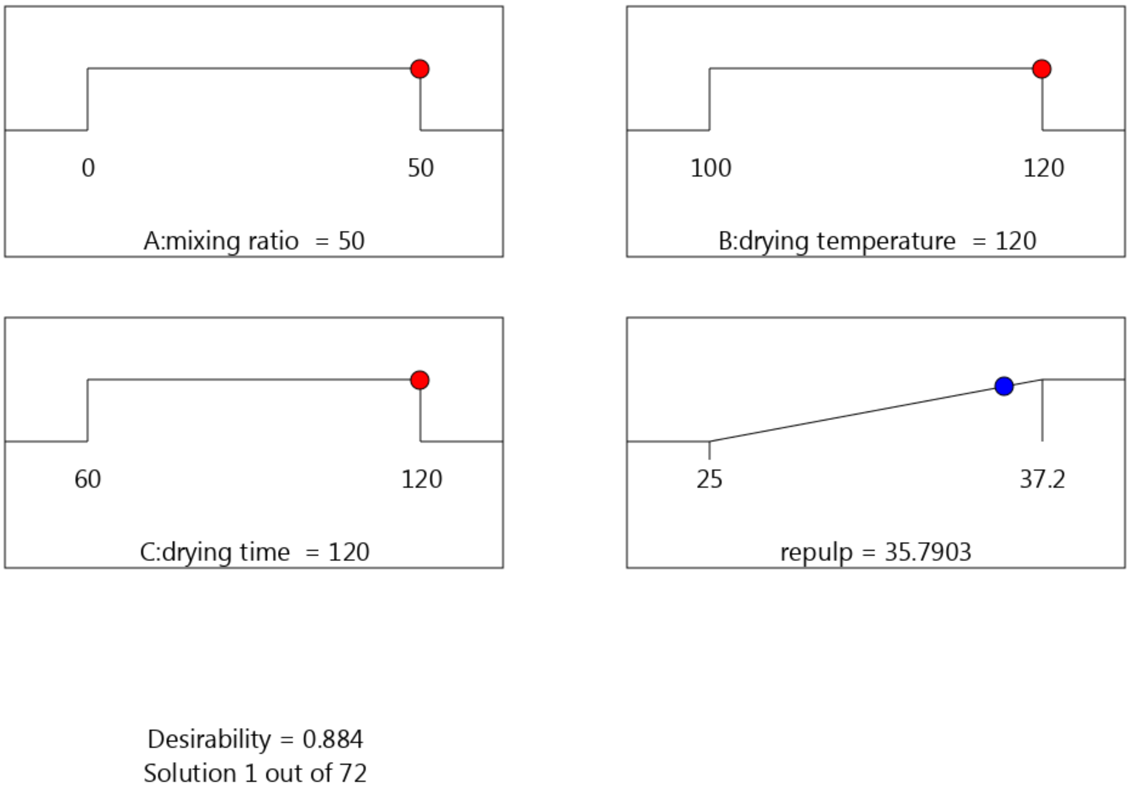

Figure 4.10: Ramp Plot of Optimization Solution for resulted pulp

5. Conclusion and Recommendation

5.1. Conclusion

The results of morphological study showed that waste beer label paper fiber have very short length, it has been blended with used paper from this properties blended fibers are satisfactory for papermaking, in part of total fibres was found to be 30.4 % ,would yield low paper strength due to this the paper produced could possible to make for a simple packaging material (good fibers for packaging) and has easy repulping capability.

It was found that the repulp yield of waste beer label paper pulp was influenced by pulping variables such as mixing ratio, drying temperature and drying time. Repulp yield was considerably influenced by mixing ratio, a slight decrease in pulp yield with respect to drying time and insignificant effect of drying temperature.

The optimized repulping conditions that has been considered high pulp yield has good, tensile and tear indices and somewhat low burst indices. But still, the blended waste beer label paper pulp can be used for production.

Generally, in addition to the suitable properties of blended waste beer label paper as a raw material for pulp and paper production, it can be alternative solution for those beer industries that contribute the pollution of the environmental. Specifically for this study the waste of “Henken” brewery with high production capacity became the burden to the place called “kosh”, consequently it can be reduce this problems by changing to usable product with perspective of environment.

Therefore, from the results of this work, it can be concluded that with different processing conditions from 25 %-37.2 % repulp yields could be prepared by mixing with ratio (25-50%) of used paper. The operating was not supported by addition of chemical for deinking and bleaching and due to this the result of repulp yield might be good for packaging material only.

5.2. Recommendation

From the above result and discussion we found that the fiber of the label is short which is more suitable for packaging and different sacks.

- One of the main advantages of this recycled beer label paper is that is very easy to shape; therefore lots of different packaging designs should be done.
- To increase the suitability of the recycled fibers for packaging and different gift pocket paper there should be various techniques of beating and chemical treatment of recycled fibers including beating and refining, chemical treatment, blending with virgin fibers, and fiber fractionation.
- Chemical treatment and blending with virgin pulp should be done in order to make high quality paper product.
- The effect of Deinking on the quality of re pulping is not studied here and bleaching. Considering the effect of deinking and bleaching may help to produce a better quality of pulp.
- Use modern process technology (mechanical refining, coatings, deinking, bonding adhesives etc.) for inherent disadvantages of recycled fibres.
- Deinking should be done in order to make food grade packing material.
- The main tough issue in paper recycling industries is collecting, transporting and sorting but from this study it is easily available raw material with no challenges of collection and transportation. Therefore it should be processed in an industrial scale since very economical and will create a job opportunities.

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Appendix

Appendix A

Appendix A_1Experimental Design and Analysis Data

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	451.54	9	50.17	70.58	< 0.0001	significant
A-Mixing Ratio	336.70	1	336.70	473.70	< 0.0001	
B-drying Temperature	5.12	1	5.12	7.20	0.0314	
C-drying Time	15.40	1	15.40	21.67	0.0023	
AB	1.82	1	1.82	2.56	0.0154	
AC	2.56	1	2.56	3.60	0.0995	
BC	0.5625	1	0.5625	0.7914	0.0403	
A^2	55.02	1	55.02	77.41	< 0.0001	
B^2	21.13	1	21.13	29.72	0.0010	
C^2	5.71	1	5.71	8.04	0.0252	
Residual	4.98	7	0.7108			
Lack of Fit	0.2275	3	0.0758	0.0639	0.9762	not significant
Pure Error	4.75	4	1.19			
Cor Total	456.51	16				

Appendix B: Supporting pictures during the study;

a

The raw material from Heineken beer factory (a)

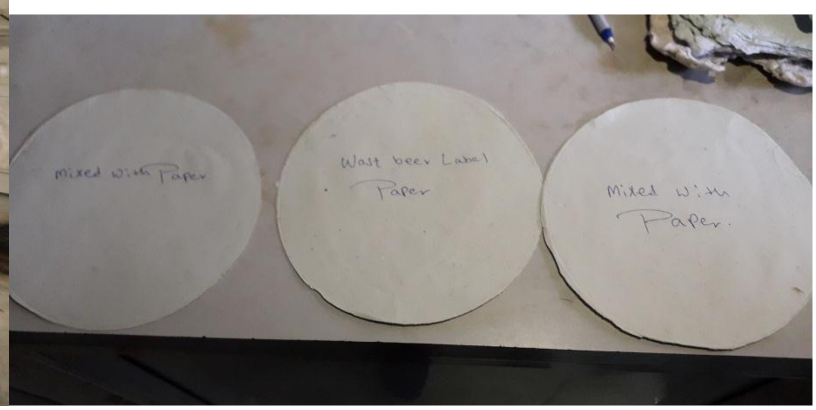
Sample paper (b)

Pulp slury (c)

The mixe A_4 paper (d)



Pulp sheet (e)



Blending the wasted beer label paper (f)

paper sheet made from wasted beer paper Mixed with A_4 paper (g)

At the laboratory of Chemical and bio engineering (AAiT)

Appendix C: Diagnostics Case Statistics

Appendix C_1: Report re pulp

Run Order	Actual Value	Predicted Value	Residual	Leverage	Internally Studentized Residuals	Externally Studentized Residuals	Cook's Distance	Influence on Fitted Value DFFITS	Standard Order
1	37.50	35.23	2.27	0.309	0.902	0.895	0.091	0.598	11
2	33.80	32.71	1.09	0.059	0.373	0.360	0.002	0.090	14
3	34.20	32.71	1.49	0.059	0.509	0.494	0.004	0.124	16
4	35.00	37.11	-2.11	0.309	-0.837	-0.827	0.078	-0.553	2
5	38.00	34.58	3.42	0.309	1.360	1.410	0.206	0.943	6
6	25.00	32.71	-7.71	0.059	-2.626	-3.681	0.108	-0.920	17
7	34.00	32.71	1.29	0.059	0.441	0.427	0.003	0.107	15
8	32.80	30.83	1.97	0.309	0.783	0.771	0.068	0.515	7
9	35.80	38.28	-2.48	0.309	-0.986	-0.985	0.109	-0.659	8
10	29.00	28.31	0.6941	0.309	0.276	0.266	0.009	0.178	3
11	31.80	32.71	-0.9059	0.059	-0.309	-0.298	0.001	-0.074	13
12	28.20	29.66	-1.46	0.309	-0.579	-0.564	0.037	-0.377	1

13	29.30	30.18	-0.8809	0.309	-0.350	-0.338	0.014	-0.226	10
14	34.80	31.53	3.27	0.309	1.300	1.339	0.189	0.895	9
15	35.80	33.88	1.92	0.309	0.763	0.750	0.065	0.501	12
16	36.00	35.76	0.2441	0.309	0.097	0.093	0.001	0.062	4
17	25.00	27.13	-2.13	0.309	-0.847	-0.838	0.080	-0.560	5

Appendix C_2 Different Alternative Optimization of the repulp

Number	mixing ratio	drying temperature	drying time	repulp	Desirability	
1	**50.000**	**120.000**	**120.000**	**35.790**	**0.884**	**Selected**
2	49.979	120.000	119.617	35.774	0.883	
3	50.000	119.834	120.000	35.773	0.883	
4	49.994	119.827	120.000	35.772	0.883	
5	50.000	120.000	119.255	35.765	0.882	
6	50.000	120.000	118.942	35.754	0.881	
7	50.000	119.577	120.000	35.747	0.881	
8	49.546	120.000	120.000	35.718	0.879	
9	50.000	119.249	119.999	35.713	0.878	
10	49.350	120.000	120.000	35.687	0.876	
11	49.562	119.633	120.000	35.683	0.876	
12	50.000	119.984	116.830	35.679	0.875	
13	50.000	120.000	115.962	35.651	0.873	
14	50.000	118.516	119.998	35.638	0.872	
15	49.995	118.393	120.000	35.625	0.871	
16	50.000	120.000	115.089	35.620	0.871	
17	50.000	118.036	119.986	35.588	0.868	
18	50.000	117.933	119.987	35.578	0.867	
19	48.521	119.996	120.000	35.556	0.865	
20	50.000	117.693	120.000	35.554	0.865	
21	49.986	120.000	113.161	35.552	0.865	
22	50.000	117.547	120.000	35.539	0.864	
23	50.000	119.398	113.972	35.520	0.862	
24	50.000	117.286	120.000	35.512	0.862	
25	49.993	120.000	110.874	35.474	0.858	

26	50.000	116.869	120.000	35.469	0.858	
27	47.660	120.000	120.000	35.419	0.854	
28	49.008	117.896	120.000	35.417	0.854	
29	50.000	120.000	109.120	35.414	0.854	
30	50.000	116.273	120.000	35.408	0.853	
31	50.000	120.000	108.469	35.392	0.852	
32	50.000	120.000	108.138	35.380	0.851	
33	50.000	120.000	107.709	35.365	0.850	
34	50.000	120.000	106.899	35.337	0.847	
35	50.000	115.562	120.000	35.335	0.847	
36	50.000	119.992	106.506	35.323	0.846	
37	50.000	115.277	119.999	35.306	0.845	
38	50.000	114.724	120.000	35.249	0.840	
39	49.915	113.977	120.000	35.160	0.833	
40	50.000	113.822	120.000	35.157	0.833	
41	50.000	119.999	100.290	35.109	0.829	
42	50.000	120.000	98.933	35.062	0.825	
43	45.037	120.000	120.000	35.004	0.820	
44	50.000	120.000	96.776	34.987	0.819	
45	50.000	120.000	96.277	34.970	0.817	
46	49.797	120.000	96.706	34.953	0.816	
47	50.000	120.000	94.231	34.899	0.811	
48	50.000	111.072	120.000	34.875	0.809	
49	50.000	120.000	92.829	34.851	0.807	
50	50.000	110.761	120.000	34.843	0.807	
51	50.000	110.285	120.000	34.794	0.803	
52	50.000	110.015	120.000	34.767	0.801	
53	50.000	109.798	120.000	34.745	0.799	
54	49.996	119.999	87.457	34.664	0.792	
55	50.000	120.000	86.967	34.648	0.791	

56	50.000	108.660	120.000	34.628	0.789	
57	50.000	107.906	119.999	34.551	0.783	
58	50.000	120.000	82.058	34.478	0.777	
59	50.000	106.851	120.000	34.443	0.774	
60	50.000	105.957	120.000	34.351	0.766	
61	50.000	105.823	120.000	34.337	0.765	
62	50.000	105.146	120.000	34.268	0.760	
63	50.000	120.000	75.058	34.236	0.757	
64	50.000	104.346	119.999	34.186	0.753	
65	50.000	104.016	119.997	34.152	0.750	
66	50.000	103.754	120.000	34.125	0.748	
67	50.000	102.557	119.999	34.002	0.738	
68	50.000	101.709	119.999	33.915	0.731	
69	50.000	100.503	119.999	33.792	0.721	
70	50.000	120.000	61.508	33.767	0.719	
71	50.000	100.000	119.992	33.740	0.716	
72	50.000	100.000	97.730	32.970	0.653	