COFFEE FILTER PAPER

Inna Molnar (thesis author 1)

Bachelor's thesis
October 2016
Degree Programme in Paper, Textile and Chemical Engineering

TAMPEREEN AMMATTIKORKEAKOULU
Tampere University of Applied Sciences

ABSTRACT

Tampereen ammattikorkeakoulu
Tampere University of Applied Sciences
Degree Programme in Paper, Textile and Chemical Engineering

Inna Molnar
Coffee Filter Paper

Bachelor's thesis 71 pages, appendices 11 pages
October 2016

Coffee filter paper belongs to the specialty paper grade. It is mainly used for producing different kind of disposable filters for brewing coffee. The main task of this filter is to detain coffee granules. It also purifies coffee from the diterpenes, which cause the cholesterol - raising effect. This ability distinguishes paper filters from other facilities for retaining granules.

The purpose of this study was to gather information on coffee filter papers and to test different papers, which are used for cone coffee makers. The stated aim was to analyse obtained results and draw a conclusion, which properties could affect process of brewing and quality of the coffee. It was quite important to reveal the most reliable and the most appropriate one in value for money and quality.

The results were obtained for the main paper properties, such as basic, strength and surface properties of the coffee filter papers. Coffee tasting tests were carried out in the coffee room with participation of seven people. The last part includes sensory analysis. All chosen coffee filter papers were examined for the presence of odor and off-flavor by nine assessors.

Judging by the results of paper mechanical tests, all chosen coffee filter papers differ relatively not much from each other and all the papers comply with the requirements. Based on sensory analysis, it can be assumed that unbleached and bamboo papers have more noticeable odor than the bleached papers. During the experiment, a clear leader among the chosen papers was not been identified.

Key words: filter paper, wet strength, porosity, coffee

CONTENTS

ABBREVIATIONS AND TERMS

cd	cross direction
EB	“Eskimo” coffee filter bags made of bleached pulp
EU	“Eskimo” coffee filter bags made of unbleached pulp
ISO	International Organization for Standardization
ISS	International Space Station
MB	“Melitta” coffee filter bags made of bleached pulp
MBa	“Melitta” coffee filter bags made of 60 % of bamboo fibers
md	machine direction
MU	“Melitta” coffee filter bags made of unbleached pulp
PAE	Polyamide epichlorohydrin
RB	“Rainbow” coffee filter bags made of bleached pulp
RU	“Rainbow” coffee filter bags made of unbleached pulp
TAPPI	Technical Association of the Pulp and Paper Industry
XB	“X-tra” coffee filter bags made of bleached pulp
XU	“X-tra” coffee filter bags made of unbleached pulp

1 INTRODUCTION

Coffee is one of the most popular beverages that are admired all over the world. People are fond of having coffee during breakfast, working hours or in the evening. Even astronauts, in spite of gravity limitations would like to have freshly brewed cup of coffee that perks up the mind and body. People's affection to coffee motivates scientists to invent special ISS (International Space Station) coffee machine which does not “afraid” of lack of Earth's gravity. (Epstein 2015)

Quality of filtered coffee considerably depends on quality of paper, which is used for filter manufacturing as well as converting processes, such as seam making. High air permeability of the paper imparts rich aroma and flavour to the beverage. High wet strength ensures the safety when the coffee filters are under high temperature and in modern machines also under the pressure. However, the main purpose of the filter is to divide fresh brewed beverage and coffee grounds.

The target of this work was to learn about different paper properties, go through whole papermaking process and test methods.

Theory part of this thesis starts from information about filter papers generally as a part of specialty papers and its application. There are several filter mechanisms that are described in the following chapter. The main theory part of this work is devoted to coffee filter papers. Which raw materials are used for manufacturing coffee filter papers, different types of filters, papermaking process, also converting and finishing processes are presented in this work. Last part presents testing methods, which were used for evaluation different properties of papers.

Experimental part includes tests with dry paper, test with paper after immersion in water, sensory analysis and coffee tests.

2 FILTER PAPERS GENERALLY

2.1 Description

When we think about paper, first we imagine printing paper, beside this there are some paper grades that are produced in large scale, such as tissue or paperboard. However, there are papers, which have special properties, depending on their end use, so called special grade papers. One of them is filter paper. High porosity is the common property for all filter papers. Additionally, they should withstand to different media and temperatures, possess the property of increased stiffness or ensure cleanliness. Moreover, filter papers have specific properties such as resistance to flow, filtration efficiency, and dust - holding capacity. (Meinander 2000, 111.)

2.2 Application

Filter papers are in great demand for different purposes. These are engine protection against contamination, laboratory filtration, variety of food and beverage applications and many others.

2.2.1 Papers for engine protection

Filter papers are used in automobile industry for the production of consumables such as air, oil and fuel filters. Usually they are impregnated to the cartridges. (Meinander 2000, 113-114.)

2.2.2 Laboratory use

There are two types of the laboratory filter papers:

1. Qualitative papers. They are produced with different levels of purity, hardness, flow rate, loading capacity, and chemical resistance. Qualitative papers could also be divided into two groups:

1) Standard filters. This kind of papers are used for routine sample filtration.
2) Wet-strengthened filters. Their usage is in clarification of liquids, which is occurred under the pressure or vacuum.

2. Quantitative papers are intended for gravimetric analysis and preparation of the samples for instrumental analysis.
    1) Ashless papers are used for general quantitative analysis.
    2) Hardened low ash papers are acid treated to remove trace metals and give to paper chemical resistance and wet strength.
    3) Hardened ashless papers are acid – hardened and provide good chemical and wet resistance. These papers are suitable for most critical filtration application. (GE Healthcare Life Sciences 2015)

2.2.3 Food industry

Papers and boards take part in separations of different products, for example clarification of liquids, such as milk, wine, vegetable oils and many others. Process filtration is occurred in presses where the products go through the high basis weight board, around 1000 g/m^2. (Hutten 2007, 294-295.)

Coffee filter papers are mainly used for producing disposable paper filters for electric drip coffeemakers. More information could be seen in the chapter 4.

Tea bag paper is usually made of thin and long abaca fibres. The basis weight is quite low from 12 to 20 g/m^2; structure is very porous. (Meinander 2000, 114.)

2.2.4 Vacuum cleaner dust bag

Vacuum cleaner dust bags made of household specialty paper, which is mainly consist of softwood pulp with adding hardwood pulp for adjusting porosity. Grammage varies from

100 to 150 g/m^2. Filters are used to retain the dust and other contaminants while passing the air through the vacuum cleaner. (Meinander 2000, 115.)

3 FILTRATION MECHANISM

According to INDA, the Association of the Nonwovens Fabrics Industry:
"Filtration is a mechanism or device for separating one substance from another."
Separations may be classified on the basis of the matter state into six categories:

1. Solids – gases.
2. Solids – liquids.
3. Solids – solids.
4. Liquids – liquids.
5. Gas – liquids.
6. Gas – gas (Hutten 2007, 1.)

There are four main mechanisms of filtration: in – depth filtration, surface filtration, surface straining and depth straining.

3.1 Surface straining

The particle, which is bigger than the pore remains in the filter. The particle has the smaller diameter moves through the filter and is not separated. In this case, all pore diameters are equal.

3.2 Depth straining

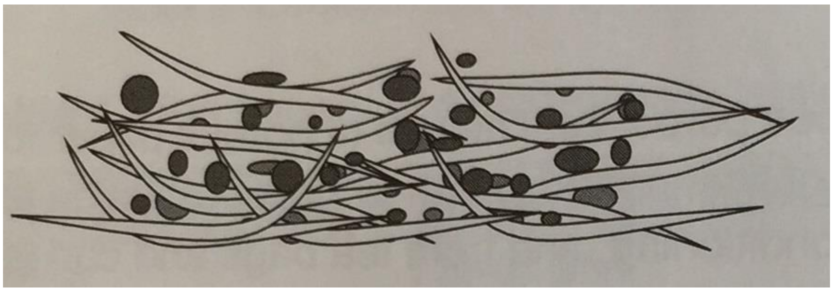
The particle penetrates the pore and goes until the place where diameter of the pore is less, than the particle. At this point, the particle becomes trapped. (Hutten 2007, 29.)

3.3 In-depth or volume filtration

The process of volume filtration (picture 1) is based on particle entering to porous structure of paper and its remaining there. During the use, the particles fills up the structure of the filter thereby decrease permeability and it has to be changed.

In this case, entry side of the filter should be more porous than the exit side. This structure helps:

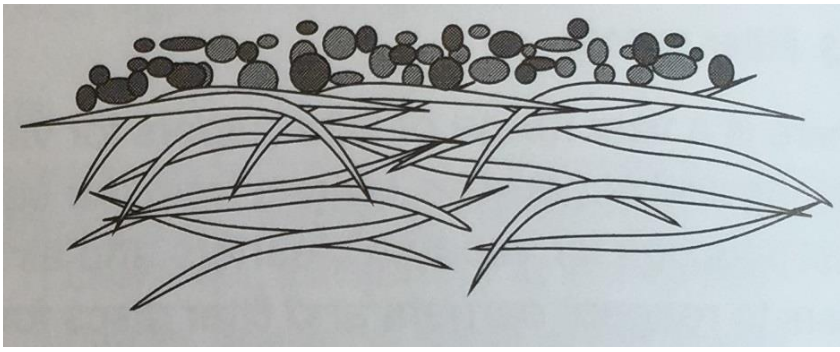
- to pass the particles toward the denser parts
- to accumulate particles through the whole volume
- to avoid going out from the exit side



PICTURE 1. Volume filtration (Meinander 2000, 112, modified)

3.4 Surface or cake filtration

The main idea of cake filtration process (picture 2) is gradual accumulation of the particles on the top surface of the filter. The thickness of the layer all the time increases, the resistance to flow and the filtration efficiency also increases with this grows. Accumulated layer resembles in appearance like a cake. In some cases, if there is possibility to remove this "cake" it can extend lifetime of the filter. (Meinander 2000, 112.)



PICTURE 2. Cake filtration (Meinander 2000, 112, modified)

4 COFFEE FILTER PAPERS

4.1 History

History of paper coffee filter starts from the beginning of the 20th century. Of course, facilities for retaining coffee grounds made of metal, linen or other materials were already invented, but for various reasons were not satisfied one housewife from Germany. Her name was Melitta Bentz. She made a hole in the bottom of the brass pot, and put blotting paper from a school notebook of her eldest son. Thus, the coffee filter was invented. On 20th of the June in 1908, Melitta Bentz was granted a patent by the German Patent and Trade Mark Office for her invention of paper coffee filter as a utility model. (Melitta 2015)

4.2 Description

Coffee filter paper is defined as high wet strength paper. It must retain as minimum 15% of its original - dry strength, some high wet - strength paper could keep up to 50%. Coffee filter paper should retain high wet strength not only during the process brewing, but also after it, lest to cause unpleasantness to person who remove it from the machine after use. (Scott, Abbott & Trosset 1995, 19)

Wet - strength paper used for making different kind of disposable filters for brewing coffee. Each filter goes through one short disposable application. The modern coffee filter papers are able to provide excellent processability. They have enough strength to withstand high speed of fully automated converting machines. Porous structure has high air permeability and allows coffee freely go through a funnel between filter walls. At the same time retain coffee grinds and prevent its sedimentation in the cup. Manufacturers are tried to invent optimum structure that will deliver the full aroma and rich taste of the coffee bean, however preserve coffee blend from interfering of undesirable flavor (neutrality of taste). (Glatfelter 2015)

Coffee filter papers could be classified according to the raw material: made of bleached or unbleached pulp. In its turn, coffee paper filters could be grouped according their capacity (in case of bag: size #1, #2, #4 and #6), seal type (heat sealable and non-heat sealable) or kind of product (pod, pad, bag or capsule). Heat sealable can be broken down into hard pods, soft pads and bags, non-heat sealable – vending, one cup coffee filter and capsules. (Glatfelter 2015)

4.3 Raw materials

Filter papers are manufactured from different kind of fiber materials. The long fibers are used for retaining high porosity as well as fine short fibers like eucalyptus or special fine long non-wood fibers like Abaca (Manila hemp) are used. Natural fibres, such as different wood pulps and others vegetable fibres have natural polymer structure. (Meinander 2000, 111; Hutten 2007, 104.)

Besides cellulose fibers coffee filter paper may consist of mixture of natural and synthetic fibers or contain glass fibers. Paper, which is used for filtration coffee grinds is not post-resin treated. Resin binders are added by beater addition to the slurry. Also, flash dried fibers are used, because they have curled structure, thereby increase porosity of the web. (Meinander 2000, 111; Hutten 2007, 81-82.)

Creation of the bonds is occurred during whole papermaking process. Hydrogen bonding, using wet end binders and binder fibers take place in the wet end of the wet lay machine. Ordinary, paper does not keep much strength in aquatic medium. Wood fibers does not bond to each other; they tend to interact with water molecules. Therefore, wet strength agents are added to the stock before the web is formed to enhance the fiber - to - fiber bonds. This kind of agents are able to adhere to the pulp by absorption and deposition. They form a network that prevent the swelling of the fibers. If consider them from molecule view wet strength agents have high weight polymeric structure. (Espy 1995, 90.)

The most used agents are positively charged cationic agents attracted to the negatively charged anionic fibers. Urea formaldehyde, cationic forms of melamine formaldehyde, polyamides and polyamines are the common used examples. First two additives are applied as the cross-linking agents, but have something different mechanisms. Urea formdehyde protects existing fiber bonds, by self – crosslinking, melamine formaldehyde beside this reacts also with cellulose. Polyamide epichlorohydrin (PAE) is very popular, because it does not emit formaldehyde fumes during drying the web.

The main functions of wet strength agents are to give strength to the web to withstand:

- the transportation through the paper machine
- the application of filtration.

Binder fibers such as polyvinyl alcohol type fibers and low melting thermobonding fibers are added for achieving good bonding. (Espy 1995, 99; Hutten 2007, 227.)

4.4 Fiber properties

As a polymer, cellulose important properties are melting point, glass transition temperature and the degree of polymerization. According to Stille (1967, 31) the glass transition temperature is the temperature at which a polymer loses its hardness and brittleness, becomes more flexible, and takes on rubbery or leathery properties. Degree of polymerization could be expressed as the number of repeat units in the polymer chain, to wit, the molecular size. Cellulose does not melt and has poor resistance to acids and basis, so it is quite applicable for manufacturing coffee filters. There is no aggressive media, only hot water and roasted coffee beans, and process brewing is carried out under increased temperatures (Hutten 2007, 104, 114, according to Stille 1967, 4.)

4.4.1 Fiber diameter

One of the most important variable that affects the filtration properties of the filter media is the fiber diameter. Hutten (2007) reviewed different filtration theories (e.g. Langmuir, Davies, Happel, Kuwabara, etc) and found the inverse relationship between fiber diameter and several variables such as flow resistance, density of the web and filtration efficiency. The bigger the fiber diameter value the less value of the others. Measuring diameter of the natural fiber is quite difficult, because it varies due to the length and from fiber to fiber. (Hutten 2007, 115-116.)

4.4.2 Fiber length

The length of the hardwood pulp fibers is 1-2 mm, the softwood pulp fibers is 3,5 - 5 mm and Abaca fibers is 6 mm. Besides pulp fibers, staple fibers are used for web consolidation. Wet laid staple fibers reach 40 mm in length and have more tendencies for machine direction orientation of the web. There is equally important property that affects web quality and its performance – ratio of fiber length to fiber diameter, so called aspect ratio. This variable affects formation and fiber orientation (Hutten 2007, 116-118.)

4.4.3 Fiber density

Density of the fiber is the variable, which is expressed in g/cm^3 shows ratio of fiber weight by its volume. It used for calculation linear density and porosity of the web (Hutten 2007, 119.)

4.4.4 Moisture content

Moisture content is a property of fiber that shows how much water it could absorb. Fibers are connected to each other by hydrogen bonding. Amount of the absorbed moisture increases with growing number of bonding sites. Moisture absorption may cause swelling of the fibers, which in its turn could increase flow resistance that makes flow rate slower. It is bad factor for filter media, which is used for liquid operations. (Hutten 2007, 120.)

4.4.5 Strength properties

There are two main strength properties of filter media fibers: tenacity is the breaking strength of the fiber and modulus. Modulus shows how flexible and rigid fiber is. Both are expressed in gr/de (denier). Denier is a weight per length, expressed in grams per 9000 metres of the material. (Hutten 2007, 122; Jaouadi, Msehli & Sakli 2007)

4.5 Coffee paper filter types

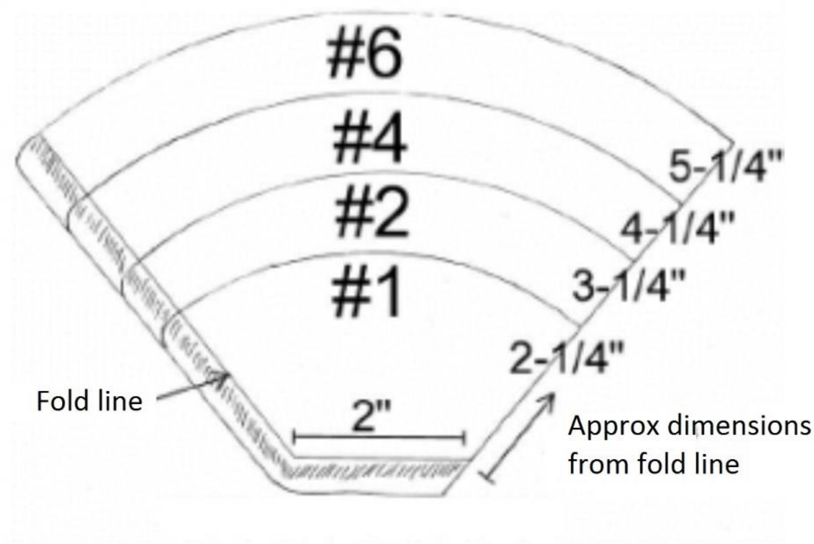
All paper coffee filters belong to the disposable type. They could be classified in different ways: depending on the used pulp, capacity, seal type and paper surface.

4.5.1 Pulp

There are two main groups of pulps, which are used in coffee filter papermaking process: wood bleached or unbleached pulp. It has become commonplace to distinguish filters made of bleached pulps from filters made of unbleached pulps. Bleached papers are white in color while unbleached papers are brown. Bleaching agent is used for improving brightness and removing lignin, that gives paper the yellow color under the sun light. However, there is also bamboo pulp, which is made from bamboo. The growing of initial natural resource - bamboo is much quicker than the growing of the wood. (Matthew Epstein's blog 2015)

4.5.2 Capacity

There are four sizes for manufacturing in case of cone filters: #1, #2, #4 and #6 (picture 3).
#1: Fits 1 cup electric cone coffee makers
#2: Fits 2-6 cup electric coffee makers and 1 cup non-electric cone coffee makers
#4: Fits all 8-12 cup cone coffee makers
#6: Fits 10 cup non-electric cone coffee makers. (Air & Water 2015)



PICTURE 3. Paper cone filters (Air & Water 2015)

4.5.3 Seal type

There are two types of coffee filters in accordance with seal: heat sealable and non-heat sealable. The first group includes hard pods and soft pads. Cone filters, one - cup coffee filter and capsules belong to the second group.

Heat sealable coffee filter papers comprised of a filtration layer and sealing layer. Filtration layer may consist of different kind of fibers such as abaca fibers, wood pulp, and cellulose rayon fiber combinations designed to meet customer requirements. Sealing layer can vary in composition and be made of polyethylene mixed with copolymers, polypropylene mixed with copolymers, or 100% polypropylene.

Non-heat sealable coffee filter papers have single layer of 100 % natural fibers, good dimensional stability and their benefit is ease of crimping (Glatfelter 2015)

4.5.4 Paper surface

Coffee filter papers are produced with smooth or creped surface (picture 4). The creping process is better explained in the chapter 4.7.5.

PICTURE 4. Smooth and creped surface (Amazon 2016)

4.6 Manufacturing

Coffee filter paper generally referred to nonwoven filter media. The forming process of nonwovens is called wet laid, because web is formed in water. This process is quite similar to papermaking process and it occurs in specially designed paper machines, because long fibers are used for making highly porous filter papers and webs. (Hutten 2007, 10.)

Wet lay process consists of two main parts: the wet end and the dry end. First part, which is shown on the figure 1, includes stock preparation, filtering the dispersion through the moving screen and forming wet sheet. The targets of the dry end are removing water from the web and producing ready sheet for making converting processes. (Hutten 2007, 220.)

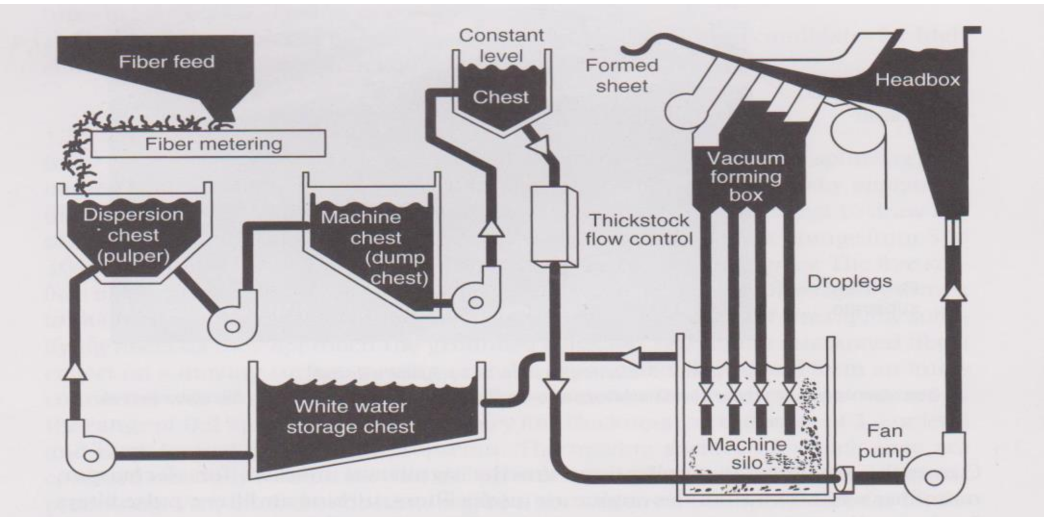


FIGURE 1. Wet end system for an inclined wire wet lay process (Hutten 2007, 22)

4.6.1 Stock preparation

There are some preparing stages before stock is pumped to the headbox of the paper machine:

- slushing
- defibration
- refining
- pulp cleaning
- proportioning.

Slushing is a process disintegration of pulps in the pulper. Defibration is more precise disintegration of any remaining fiber bundles. Refining makes fibers more flexible, improves their bonding ability (enhance tensile, bursting, folding and internal bond strengths), also length of fibers could be controlled by this process. Centrifugal cleaning is used for removing high density or very low-density contaminants, screens removes large contaminants. Recipe of fibers and other ingredients depends on product quality and performance. Stock flow and its consistency are precisely controlled for achieving the targeted grammage of end product. (Hutten 2007, 221; KnowPap, a)

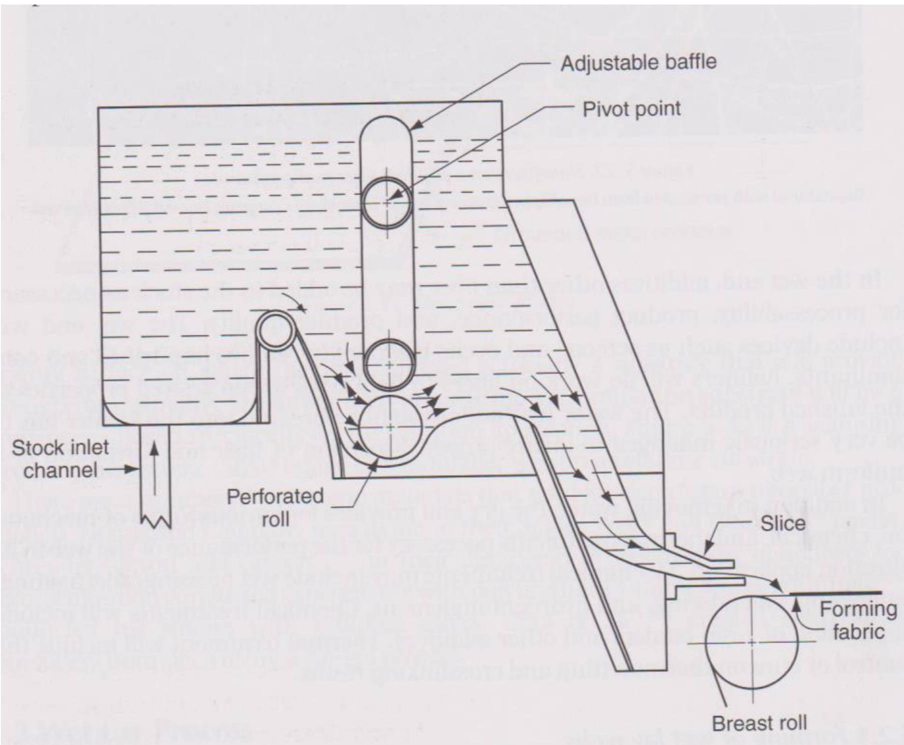
4.6.2 Wire section.

Most part of the water is removed in wire section. This process is controlled in order to achieve uniform fiber. The important task of the wire section is to bring the web to sufficiently dry content for runnability reasons. Generally, wire section consists of three main parts:

- the headbox approach piping
- the headbox
- the forming section

Just before stock is pumped to the headbox, it should be diluted with extra water. The stock consistency in wet lay nonwoven machine varies from 0,1 % and even lower. Essentially, headbox of the paper machine is a hydraulic device that dispenses pulp stock evenly in the cross direction onto a moving wire with desired speed. (KnowPap, b)

Fourdrinier headbox is traditional papermaker's headbox. It provides a baseline for comparison to formers that are used for forming long fibered wet lay nonwovens. As could be seen on the picture 5, slurry is sent from a pond through a long, narrow, horizontal opening, called slice. Aqueous slurry spreads out, forms horizontal layer over the wire. The thickness of the layer is usually within 25-100 mm. Fibers are filtered by the wire, water is drains through it and wet laid sheet is formed on the surface.



PICTURE 5. Fourdrinier headbox (Hutten 2007, 222)

Along with Fourdrinier inclined wire machine is also used for production long fiber specialty papers. Stock consistency in that case is below 0,02 % and this allows to form homogeneously extremely long fibers such as Abaca. Voith multilayer HydroFormer is used for production two – or three layer long - fiber paper or nonwoven material with one headbox (figure 2). Such headbox is equipped with two or three feed systems, consisting of a manifold and a turbulence block. Flexible lamellas separate the inflow suspension so that first the bottom layer, then the middle layer and finally the top layer are dewatered. (Voith 2014, 27-30.)

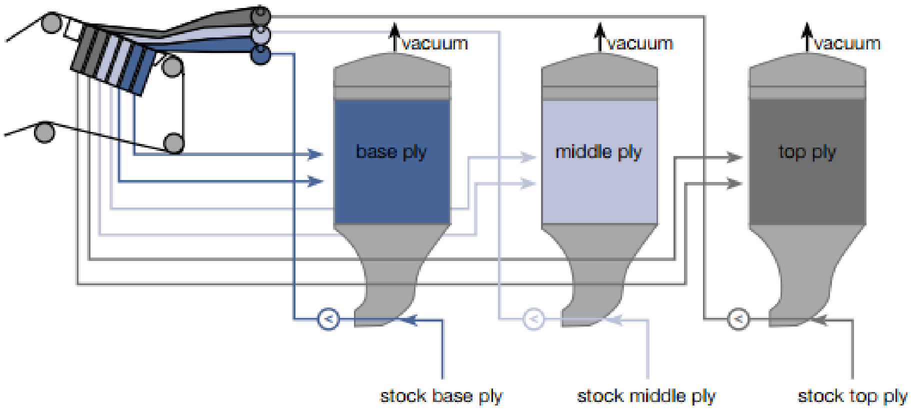


FIGURE 2. HydroFormer (Voith 2014, 28)

Multilayer HydroFormer is commonly used for producing paper for products with unique characteristics such as high quality tea bags and coffee pads (picture 6). (Voith 2014, 30).

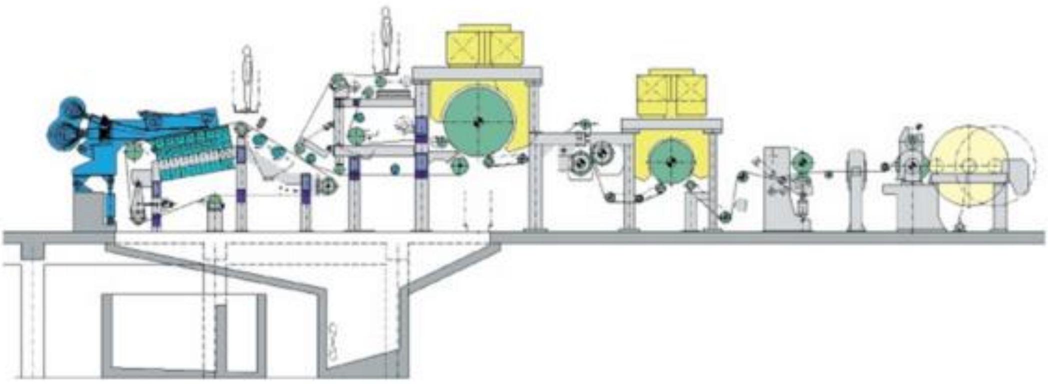
PICTURE 6. Filter paper for coffee pads (Voith 2014, 28)

4.6.3 Press section

The main functions of press section are removing of water and consolidation of the sheet. In wet presses, suction slots are used for performing water removal. However, in contrast to the conventional papermaking process dry content can get down maximum to 40-50%, because of avoiding caliper reduction. (Hutten 2007, 226.)

4.6.4 Drying section

For providing sufficient bulk and high porosity, wet pressing could be avoided completely, web is dried on a through air dryer (TAD) (picture 7) (Mirsberger 2013, 837).



PICTURE 7. Machine with inclined wire former and through air dryer (Mirsberger 2013, 837)

Thermal drying is the common way of removing the rest of the water. There are several types of thermal drying:

- Steam heated can dryers (figure 3)

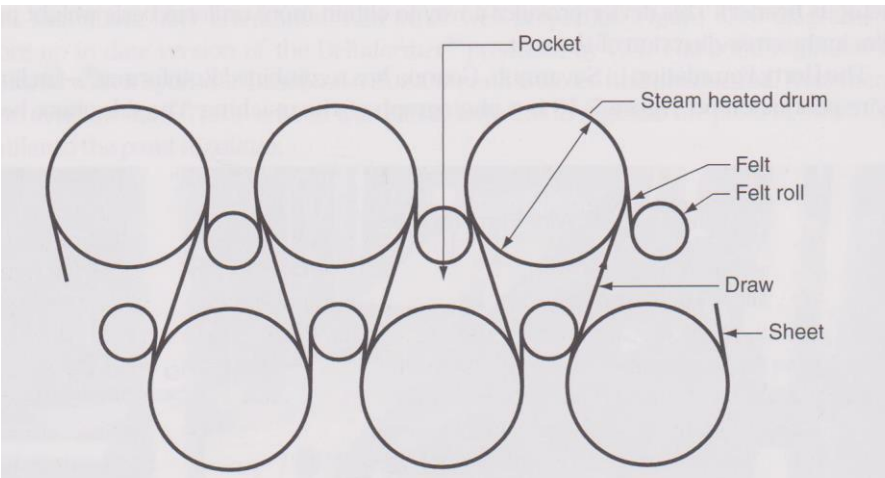


FIGURE 3. Two – tier cylinder drying configuration (Hutten 2007, 226)

- hot air dryers: impingement air and through – air drying. These methods are preferred for filter media, because bulk remains at the sufficient level
- infrared devices

- microwave heating.

First two methods are the most common for drying wet laid nonwovens. All these methods could be applied separately or in combination. (Hutten 2007, 226.)

Dryer felts – woven fabrics are used for support and transport the web during the drying process. They should be porous enough to perform water escape, but not too much, to avoid the rupture. Pressure that is generated between the dried web and the felts leads to reducing of the bulk and paper web becomes denser. That is why some wet lay filter mills abandoned the use of dryer felts, despite of loss efficiency (KnowPap, c; Hutten 2007, 226.)

4.6.5 Finishing and converting processes.

There are number of processes, which are needed for further processing in or outside the mill: creping, slitting, rewinding, die cutting and bag making (Hutten 2007, 229).

Creping is a process increasing the surface area for filtration. Generally, this process is performed by Yankee dryer cylinder when tissue paper is made. Yankee cylinder is usually not used for making filter media creping, instead of it press rolls (wet press or size press) implements this process by pushing against creping doctor so that the web bunches up against the blunt edge of the doctor as shown in the figure 4. Machine speed is decreased in order to avoid pulling out the crepe. (Hutten 2007, 230-231.)

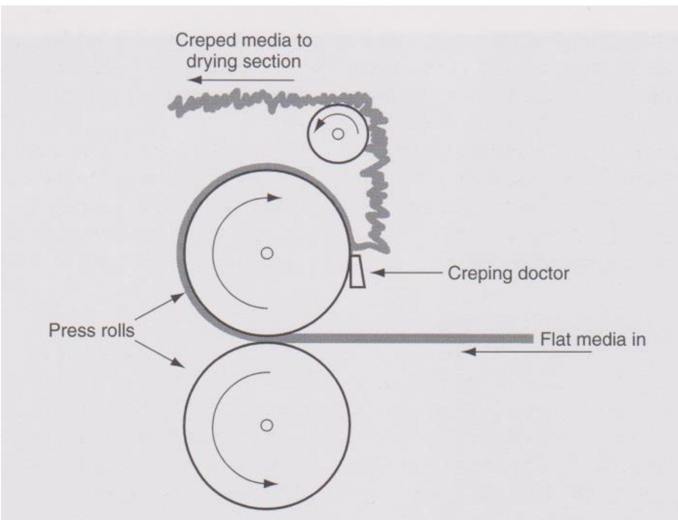
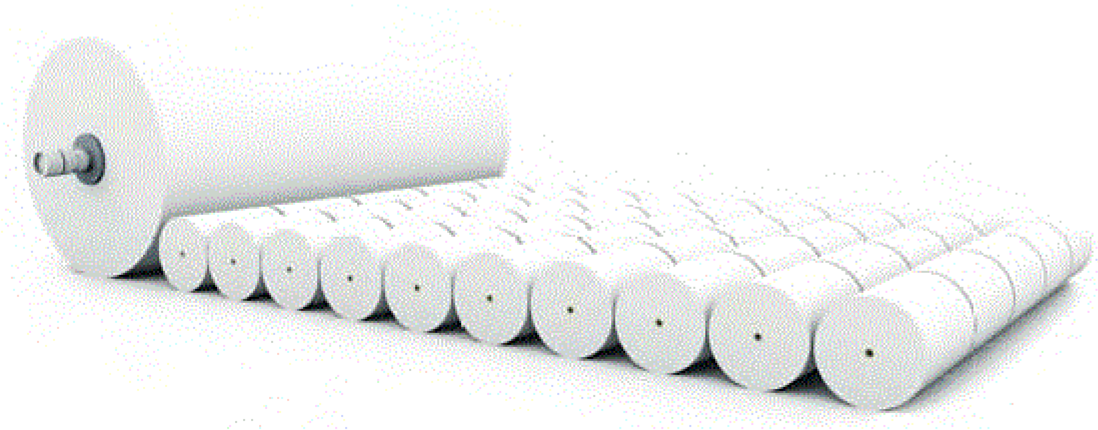


FIGURE 4. Creping press (Hutten 2007, 232)

The result of rewinding and slitting is illustrated in the picture 8. When machine reel is wound up on core, it needs to be prepared for later processing. For that purpose, jumbo rolls are rewound to the customer-desired diameter rolls or for better usability in the mill. Frequently, rewound rolls also are sent to be cut in slitter to obtain desired width. Low quality edges are trimmed and, it should be noted, this is the most waste produced process, can be as high as 3 %. (Hutten 2007, 231-233.)



PICTURE 8. Slitting and winding (KnowPap, d)

Bag making process includes folding, trimming, shaping, pleating of the edges and packaging. Coffee filter paper is used for food processing filtration, therefore there are hygienic issues in process control and packaging. (Hutten 2007, 233.)

5 TESTS WITH DRY PAPER

Four different producers of coffee filter paper were chosen for experimental research: Eskimo, Melitta, Reinbow and X-tra. Bleached and unbleached type of paper of each brand were purchased. Additionally, third type of Melitta was delivered from Germany. This kind of filter bags is interesting to research, because they contain 60 % of bamboo fibers. So, there were totally nine grades.

Significant basic properties, such as basis weight, thickness, moisture content of the coffee filter papers were measured. Fiber orientation was determined mainly for evaluation strength properties, such as tensile and tear strength, which are very dependent on fiber orientation. Bursting strength of the paper was defined on the grounds of the strength of filter walls. Implemented surface properties include air permeability and roughness. In addition, speed test was performed. The main idea of air permeability is to define the speed of air passage through the paper, speed test showed the water passage through the paper. The attempt to determine the seal strength was implemented in the experimental part of the work.

The target of this work was to define which properties of paper were essential and affect the quality of the filter as a product.

All tests were carried out at 23°C + 1°C and 50 + 2% relative humidity, which is ISO standard.

5.1 Basic properties

Basic properties of different coffee filter papers, which were evaluated are presented in the table 1.

TABLE 1. Basic properties of different coffee filter paper

Method	Units	Equipment	Standard	№
Basic weight (grammage)	g/m^2	scales SCALTEC CBS32, d=0,0001g	ISO 536, Tappi T 410	10
Thickness (caliper)	µm	Thickness micrometer Lorentzen&Wettre, Code 250	ISO 534	10
Moisture content	%	Lorentzen & Wettre Moisture Tester, Code 862	-	10
Fiber orientation	-	L&W TSO Tester, Code 150	-	10

5.1.1 Basis weight.

The basis weight (grammage) is the weight of paper or paperboard per unit area and it could be expressed in square meters in grams (g/m^2), pounds per 1000 square foot or weight in kilograms or pounds per ream (500 sheets) of a specific size. (Pulp and Paper on the Web 2015)

The standard ISO 536:2012 Determination of grammage was used. For that purpose, the specimens, 10 pieces of each denomination were cut as a rectangle with 8 cm width and 12,5 cm length and weighted by using scales SCALTEC CBS32, with accuracy d=0,0001g. There was Fonly a limited area available that is why minimum possible area of 100 cm^2 was used. The average value of weight for each item was calculated by the formula (1):

$$m_x = \frac{m_1+m_2+\cdots+m_n}{n} \quad (1)$$

where
m – the mass of a test specimen, in grams
n – the number of tests

The basis weight is calculated by the formula (2):

$$g=\frac{m}{A} \times 10000 \quad (2)$$

where

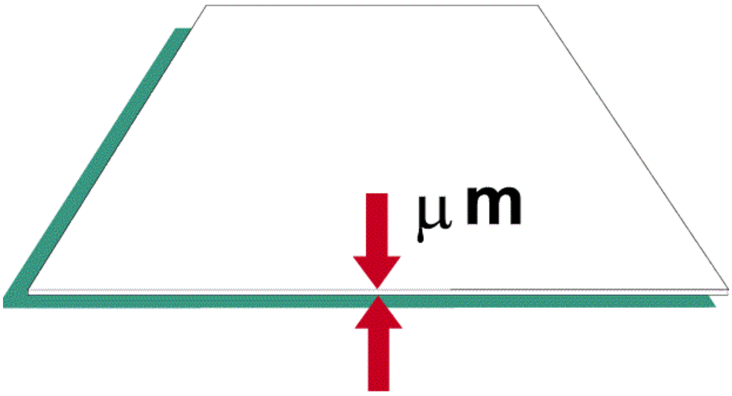
g – the basis weight (grammage), in grams per square meter

m – the mass of a test specimen, in grams

A – the area of the test specimen, in square centimetres

5.1.2 Thickness

Thickness (picture 9) is a structural characteristic of the paper. It shows perpendicular distance between the top and the bottom surfaces of the paper under specified conditions. Thickness of paper usually is expressed in micrometers, only in United States in America the units are inches. Another related property is thickness uniformity; it affects strength, optical properties and roll quality. (Scott, Abbott & Trosset 1995, 55.)



PICTURE 9. Thickness (KnowPap, e)

The measurements, ten times for each denomination, were performed according to the ISO 534 Determination of thickness, density and specific volume. Each sheet was placed between two parallel measurement surfaces and it was set under specific load for the length of the measurement. The other surface must move at right angles against the other measurement surface. The thickness measurements were made with a precision of micrometer. The results were printed by the testing machine.

5.1.3 Moisture content

All grades of paper contain from 2 % to 12 % of moisture. The amount of the moisture affects almost all paper properties, especially strength properties. Also it has influence on calendaring, printing and converting process. (Pulp & Paper Resources & Information Site 2015)

Paper moisture content could be expressed by the following formula (4):

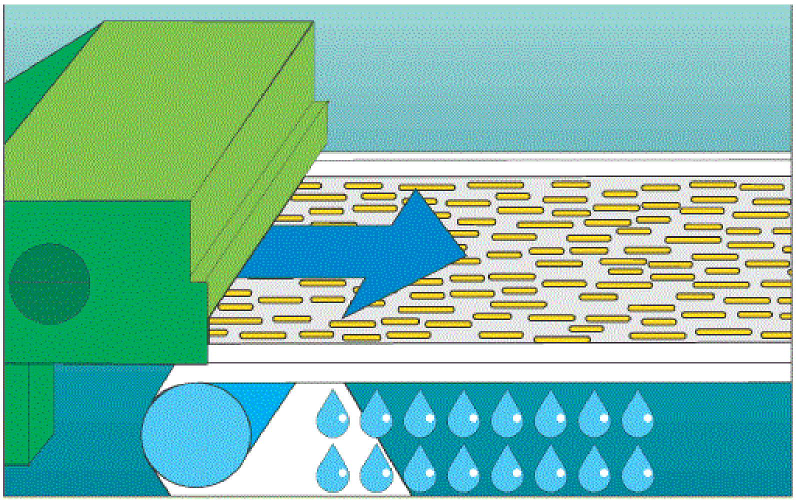
$$M = \frac{m_w}{m_p} * 100\% \qquad (4)$$

where
M – moisture content of the paper
m_w – mass of the water
m_p - mass of the paper

Measurements were processed in Lorentez & Wettre Moisture Tester. The number of tests was 10 of each paper. The sample was placed to the orifice, before this the value of basis weight was chosen and the data was read from display of the machine, expressed in percent.

5.1.4 Fiber orientation

Fiber orientation or directionality is a structural property of the paper, it shows how the fibers is mainly distributed in the sheet. It is caused by speed difference of the moving wire and the coming stock. Fibers pass from the headbox slice are already oriented the same as wire run. Fibers will align lengthwise, if speed of the wire is higher or equal to the stock velocity. So most of papers have the definite direction due which most of the fibers are oriented and it coincides with the direction of the machine run, so called machine direction (picture 10). The cross direction is the direction of paper at right angles to the machine direction. Many other properties of paper, such as tensile or tear strength vary so much due to the directionality that is why they usually determined in both directions. (KnowPap, f; Pulp & Paper Resources & Information Site 2015)



PICTURE 10. Fiber orientation (KnowPap, f)

The results were obtained from L&W TSO Tester. Each sample was placed to the measurement orifice and processed.

5.2 Strength properties

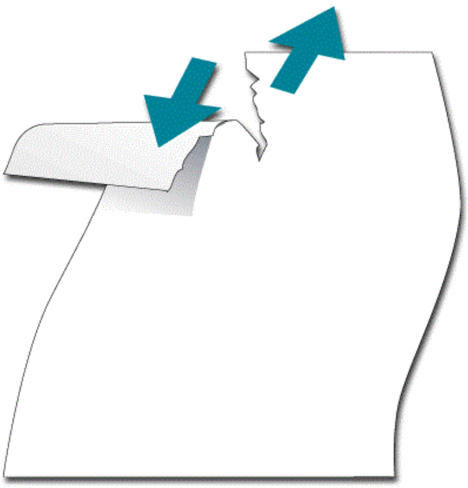
Strength properties of different coffee filter papers, which were evaluated are presented in the table 2.

TABLE 2. Strength properties of different coffee filter paper

Method	Unit	Equipment	Standard	№
Tear strength	mN	L&W Tearing Tester	ISO 1974	10
Tensile strength	kN/m	L&W Tensile Strength Tester	ISO 1924-3	10
Bursting strength	kPa	L&W Bursting Strength Tester	ISO 2758	10

5.2.1 Tear strength

Tear strength (picture 11) is the ability of the paper to resist the applied tear force. This property is quite important for runnability of the web. Basis weight and moisture content affect the tearing resistance. Tear strength increases with increasing the grammage. Greater the moisture content – less the tearing resistance.



PICTURE 11. Tear strength (KnowPap, g)

Elmendorf method, which is explained in ISO 1974 Determination of tearing resistance was used. Tests were carried out in both directions: machine and cross directions. A test specimen dimensions were 63 mm in length and 53 mm width. The special paper cutter was used; it is designed to give a precise 63 mm length with parallel edges. One sample was put into measuring device, was precut and processed.

Tear strength index in mNm^2/g was calculated by the following formula (5):

$$X = \frac{F}{g} \tag{5}$$

where

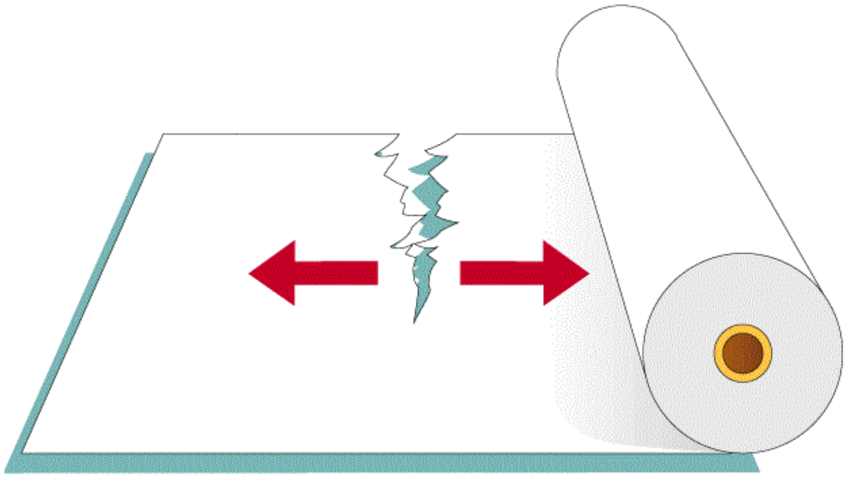
X is the tear index, in millinewton square meters per gram ($mN \cdot m^2/g$);

F is the tearing resistance, in millinewtons;

g is the grammage, in grams per square meter (g/m^2).

5.2.2 Tensile breaking strength

Tensile strength (picture 12) is defined as a highest loading rate that paper or board can withstand without rupture when being stretched in the surface direction. Basis weight, formation, fiber orientation, moisture and ash content have influence on the tensile strength of the paper. Suggested reported unit is kilonewton per meter. (KnowPap, h)



PICTURE 12. Tensile strength (KnowPap, h)

Measurements were done 10 times in each direction. Samples were cut in the form of strip with width 15 mm and long enough to be clamped in the clamps.

Tensile strength index, $X_{tensile}$ in Nm/g could be calculated by the formula (6):

$$X_{tensile} = \frac{F_{tensile}}{g} \quad (6)$$

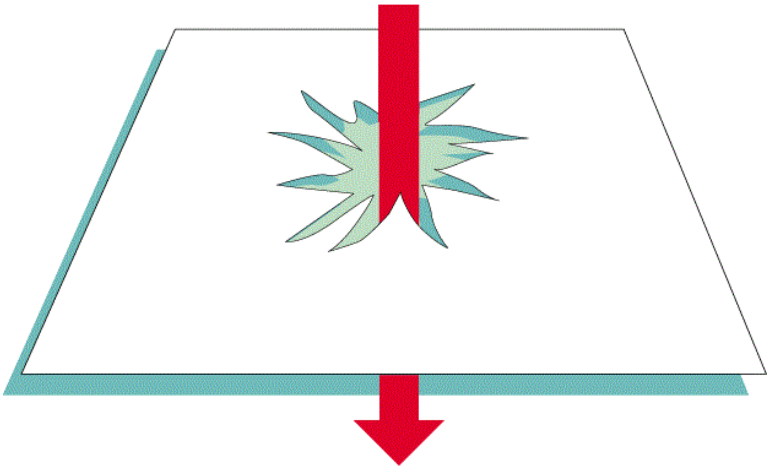
where

$F_{tensile}$ is the tensile strength, in kilonewtons per meter;

g is the grammage, in grams per square meter.

5.2.3 Bursting strength

The bursting strength (picture 13) is the maximum hydraulic pressure that the sample can withstand without breaking. It is expressed in kilopascals. Bursting and tensile strengths are considered as the highly correlated properties and they have the same affecting factors. (KnowPap, i, Scott, Abbott & Trosset 1995, 77.)



PICTURE 13. Bursting strength (KnowPap, i)

The principle of the method is that hydraulic fluid is pumped at a constant rate builds the diaphragm, which cause the rupture of the sample. The measurements were done from inner side of the bag, it seemed to me more logic, because pressure is caused from inside during the use of the filter. The number of tests were ten of each nomination.

The burst index X_{burst}, in kilopascals square meters per gram, was calculated by the formula (7):

$$X_{Burst} = \frac{F_{Burst}}{g} \qquad (7)$$

where

F_{Burst} is the mean bursting strength, in kilopascals;

g is the grammage of paper, in grams per square meter.

5.3 Surface properties

Surface properties of different coffee filter papers, which were evaluated are presented in the table 3.

TABLE 3. Surface properties of different coffee filter paper

Method	Unit	Equipment	Standard	№
Air permeability	s	Gurley densometer	ISO 5636	10
Roughness	ml/min	Bendtsen roughness Tester	ISO 8791-2	10

5.3.1 Porosity and air permeability

These two properties of the paper often used interchangeably, but it is a misconception. According to Scott, Abbott and Trosset (1995, 55), porosity is a ratio of pore volume to total volume of the sheet. Air permeability is a property of paper that allows air to flow through it under a pressure difference across the sheet. For example, we have two different papers with the same porosity value, one has many small pores, another – larger in diameter, but fewer in number. These two papers will have different value of air permeability. Filter paper requires a high air permeability to achieve good liquid flow rate (Scott, Abbott & Trosset 1995, 61.)

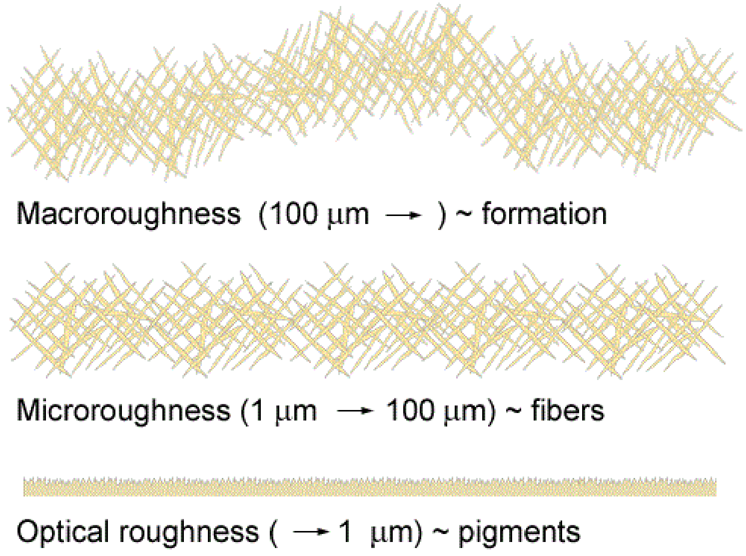
Porosity has a significant impact particularly on the flow of liquids and gases in the paper. The specific characteristics such as resistance to flow and filtration efficiency depend on porosity and pore size distribution. (Meinander 2000, 111.)

Pore size is usually expressed as pore radius that could be measured by the mercury penetration method (KnowPap, j).

The procedure of the test was according to the ISO 5636 Determination of air permeance: Gurley method. Test sample was placed between the clamping plates and the time in seconds was recorded. Result is a number of seconds that is needed for passing 100 cm^3 of air through the paper. Only inner side was tested. The number of tests were ten of each nomination.

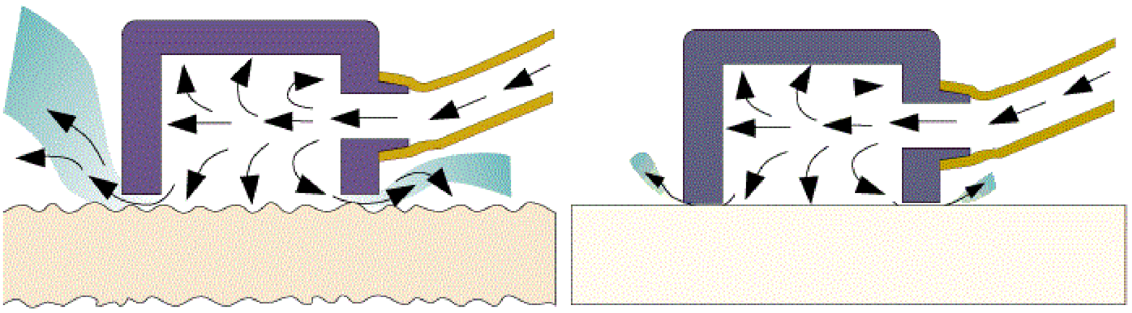
5.3.2 Roughness

Roughness is asperity of the paper surface. Roughness can be classified depending on scale of the unevenness into macroroughness, microroughness and optical roughness (picture 14).



PICTURE 14. Roughness components (KnowPap, k)

There are two methods for measuring roughness: Bendsten (expressed in milliliter per minute) and the Parker Printsurf (expressed in micrometers). They are based on determination of the air flow passing between the edge of the metal ring and the surface of the test sample at a certain pressure under the given conditions (picture 15).



PICTURE 15. Roughness of surface (KnowPap, k)

Bendtsen roughness Tester was used for obtaining results. The sample was put to the measurement orifice of machine, processed and results were printed.

5.4 Seal strength

Seal strength test was carried out on the universal testing machine Testometric M350-5 CT. The width of the sample was 25 mm. The edges were clumped; the seal should be in the middle between clumps. The information data and graphics of the process were evaluated on the computer screen. The number of the samples were 10 for each nomination.

5.5 Water flow speed test

The procedure of the test was found among You Tube videos and sparked my interest. All papers were tested according to the following procedure. Each filter bag was placed to the plastic filter holder from the coffee maker. Holder was put on the reservoir for collecting the water. Two deciliters of boiled water were poured to the filter. Time of the water passage through the filter was recorded by the stopwatch. The procedure could be seen by using following link. Test was repeated ten times for each nomination. (You Tube, 2016)

6 TESTS WITH WET PAPER

Coffee filter paper must retain strength when it comes in contact with water in use. It should withstand tear, rupture or falling apart to avoid getting the granules into the beverage. (Scott, Abbott & Trosset 1995, 75.) Strength properties after immersion in water of different coffee filter papers, which were evaluated are presented in the table 4.

TABLE 4. Strength properties of different coffee filter paper after immersion in water

Method	Unit	Equipment	Standard	№
Tensile strength after immersion in water	N/m	L&W Tensile Strength Tester	ISO 3781	10
Bursting strength after immersion in water	kPa	L&W Bursting Strength Tester	ISO 3689	10

6.1 Tensile strength after immersion in water

Wet tensile strength is a maximum tensile force per unit width that a wet sample could withstand without rupture.

Wet tensile strength could be calculated by the formula 8:

$$\sigma_{wet} = \frac{\bar{F}_{wet}}{b} \tag{8}$$

where
$\boldsymbol{\sigma}_{wet}$ – wet tensile strength, in kilonewtons per meters
F_{wet} is the mean maximum tensile force, in kilonewtons;
b is the width of the dry test piece (15 mm), in meters.

Wet tensile strength retention is measured as a ratio of the tensile strength of a wet test piece to that of another test piece from the same sample in the dry, conditioned state. It is calculated by the formula 9:

$$\sigma_R = \frac{\sigma_{wet}*100}{\sigma_{dry}} \tag{9}$$

where

σ_R - wet tensile strength retention, in percent;

σ_{wet} - is the wet tensile strength, in kilonewtons per meter;

σ_{dry} is the tensile strength in the dry, conditioned state, in kilonewtons per meter.

Coffee filter paper is a very absorbent paper that is why as it was recommended in the ISO 3781 (chapter 9) only the center portion of the test piece was wetted.

6.2 Bursting strength after immersion in water

According to the ISO 3689 standard, bursting strength after immersion in water is the maximum pressure that paper sheet, which was immersed in water for specific time could resist without rupture.

The number of tests were ten of each nomination. The samples were immersed for one hour in ionized water then the procedure was the same as for determination of the bursting strength. Mean bursting strength, P, in kilopascals, after immersion in water is calculated by the formula 10:

$$P = \frac{B}{N} \tag{10}$$

where

B - is the mean bursting strength, in kilopascals;

N - is the number of test pieces burst together

Also bursting strength retention, P_R, in percent, is calculated by the formula 11:

$$P_R = \frac{P_{wet} * 100}{P_{dry}} \tag{11}$$

where

P_{wet} – is the bursting strength of paper immersed in water, in kilopascals;

P_{dry} - is the bursting strength of the same paper in the dry state, in kilopascals.

7 COFFEE TESTS

Using paper coffee filter may have influence on the taste of the beverage. Paper could impart to coffee extra odor or flavor. Different paper could also have different characteristic of filtration efficiency, let to pass more or less amount of oils, which are contained in the coffee bins. The purpose of the coffee tests was to evaluate the quality of the beverage using different paper filters.

7.1 Tasting tests

One kind of coffee (Paulig, Juhla Mocca) and three different filter bags (bleached, unbleached and bamboo) of one brand Melitta were taken for the experiment. The coffee maker Mocca Master was used for the test. Fresh brewed coffee was poured to the cups. Three numbered cups with coffee and one cup with water were presented for each assessor for evaluation. Assessor should examine the aroma, body, flavor, extent of acidity, finish (is taste of the coffee stays in the mouse short or long time) and presence or absence of any sediment. Tasting tests were implemented in two different days with the same coffee and filters, but cups were different. The paper cups were used on the first day and glass cups were used on the second day.

Preparing process:

1. Certain amount of cold, fresh water (1250 ml) was put to the water reservoir
2. Filter paper bag was placed to the filter container
3. Right amount of grounded coffee beans (68,75 g) was put to the filter, according to the Specialty Coffee Association standard it shall be 0,055 g coffee per 1 ml.
4. The start button was pushed
5. The beverage was stirred, because strong coffee is located on the bottom and weak is on the top (Paulig 2016, Specialty Coffee Association 2016)

7.2 Turbidity

Turbidity test was carried out according to the standard “ISO 7027 Water quality. Determination of turbidity”. Portable Turbidimeter Model 2100P ISO was used in this experiment. The device was calibrated before use. Ten milliliters of diluted coffee were poured to the cell. Dilution was in ratio 1 part of coffee and 4 parts of distilled water. The cell was closed, wiped and processed. The result was read from the display.

8 SENSORY ANALYSIS

Sensory analysis is needed for evaluation consumer products by human senses. Two senses: smell and taste were used in this work. Sensory evaluation was used to compare different coffee filter papers and assess a range of existing extra odor or flavor. (Letherhead Food Research 2016)

8.1.1 Odor

The standard SFS-EN 1230 part 1 was used for evaluation the presence or absence of paper odor when using filter. The following procedure was implemented for carrying out the test. Six square decimeters of paper, pre-cut into strips with dimensions as minimum 1 cm per 5 cm were placed to the flat bottom flask. The flask was closed for 20 – 24 hours. The evaluation was done by assessors using 0 - 4 scale, where 0 is no perceptible odor; 1 is odor just perceptible (difficult to define); 2 is weak odor; 3 is clear odor; 4 is strong odor.

8.1.2 Off – flavor (Taint)

The second part of the standard SFS-EN 1230 clarifies the test method for evaluation of presence or absence of the taint. The sampling procedure was the same like in previous test. For the test 50 ml of solid sodium chloride solution was poured into the jar and solid sodium chloride was added a little. A suitable amount of test substance and 20 g of grated chocolate were placed in a Petri dish in the jar. The jar was closed tightly and stored for 44 - 48 h at (23 ± 2) °C in the dark. The evaluation scale is also from 0 to 4, as it was in previous test.

9 RESULTS AND CONCLUSIONS

Nine different filter papers were used for the experiments: four bleached papers, four unbleached papers and one made of 60 % of bamboo fibers. All tests could be divided into four sub – groups:

- mechanical tests with paper
- coffee tests
- sensory analysis.

9.1 Tests with paper

All papers were examined by its basic, surface and strength properties. Strength properties were measured in two states of paper: dry and wet. In addition, seal strength and speed of passing water throw the paper surface were determined.

9.1.1 Basic properties

The basis weight of chosen coffee filter papers varies from 51,9 g/m^2 to 60,8 g/m^2 (table 8). According to these results, Eskimo and X-tra, as well as Rainbow and Melitta have approximately the same values of the basis weight.

The basis weight is very important in comparison of strength properties of papers. For this reason, the value of the basis weight was used for calculation tear, tensile and bursting strength indexes (table 12, 14, 16).

The thickness of paper is decreased with decreasing of basis weight. In the figure 5 could be seen that values of thickness for Eskimo papers are higher than the values for X-tra while having approximately the same basis weight. One of the reasons could be the creping process, which makes the sheet bulky or less dense. It could be supposed that Eskimo papers have better filtration efficiency than the X – tra, because surface of filtration in Z – direction is bulkier. Melitta and Rainbow have almost the same values of the thickness.

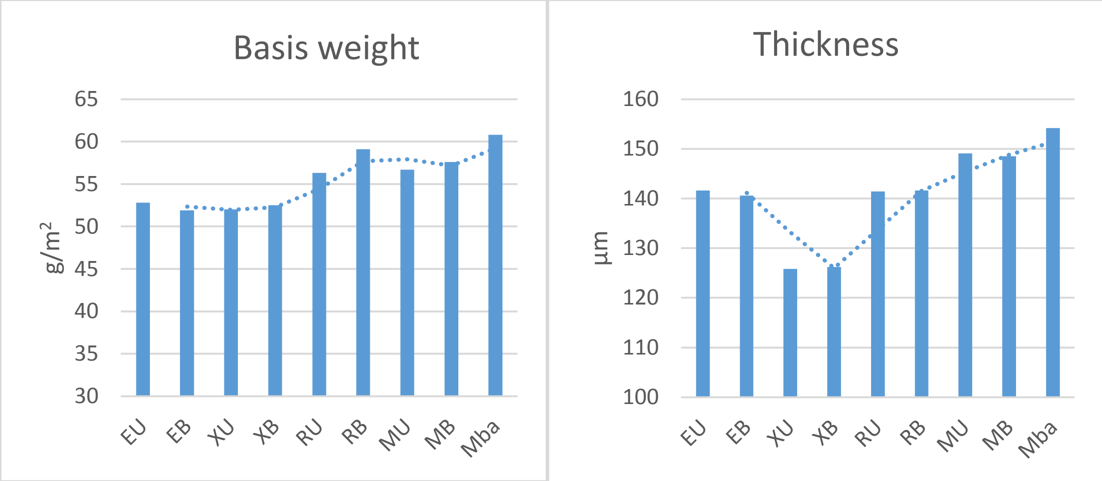


FIGURE 5. Basis weight and thickness of different coffee filter papers. E is Eskimo, X is X-tra, R is Rainbow, M is Melitta, U is unbleached, B is bleached and Ba is bamboo.

Moisture content of coffee filter papers (table 10) varies within 0,6 % and this deviation could be assumed negligible (figure 6).

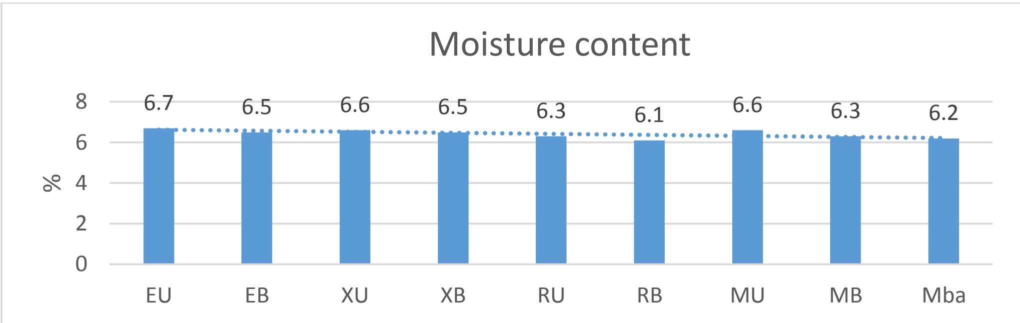


FIGURE 6. Moisture content of different coffee filter papers. E is Eskimo, X is X-tra, R is Rainbow, M is Melitta, U is unbleached, B is bleached and Ba is bamboo.

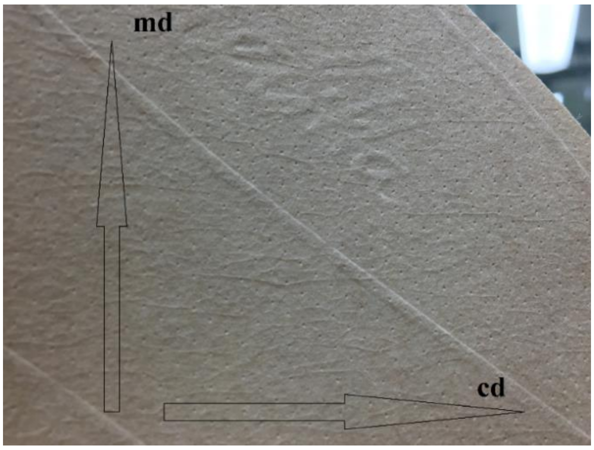
9.1.2 Strength properties

The tear strength was measured in both directions (table 11). The tester was calibrated first for four test pieces at a time, but results could not be defined, because of high tear strength. Then the machine was calibrated for two test pieces, the same result was obtained for almost all papers, which were cut in cross direction. Only one test piece at a time gave appropriate result. Even then, the result for X-tra unbleached paper could not be defined. The break line went obliquely more than 10 mm from the direction of the slit, which is unacceptable according to the ISO 1974 standard (picture 16). The results were rejected.

Tear strength depends on the fiber length. Coffee filter paper made of very long fibers that is why the values are quite high.

PICTURE 16. X-tra unbleached coffee filter paper test pieces (Photo: Inna Molnar 2016)

On the figure 7 could be seen that values of tear strength in cross direction are higher than in machine direction, because it is harder to break across the fibers than if fibers go parallel, like it is in machine direction. Even though in most cases this difference is not so substantial, because very long staple fibers are also located in cross direction and thereby increase the tear strength in machine direction (picture 17).



PICTURE 17. Melitta unbleached coffee filter paper (Photo: Inna Molnar 2016)

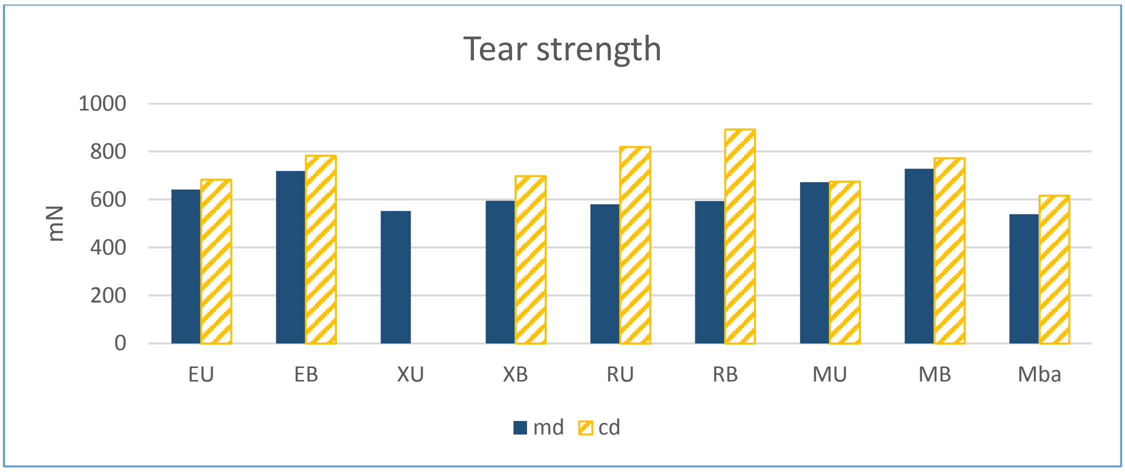


FIGURE 7. Tear strength of different coffee filter papers. E is Eskimo, X is X-tra, R is Rainbow, M is Melitta, U is unbleached, B is bleached and Ba is bamboo.

Due the basis weight of coffee filter papers is different, the tear strength index (figure 8) helps to compare the tear strength of the papers.

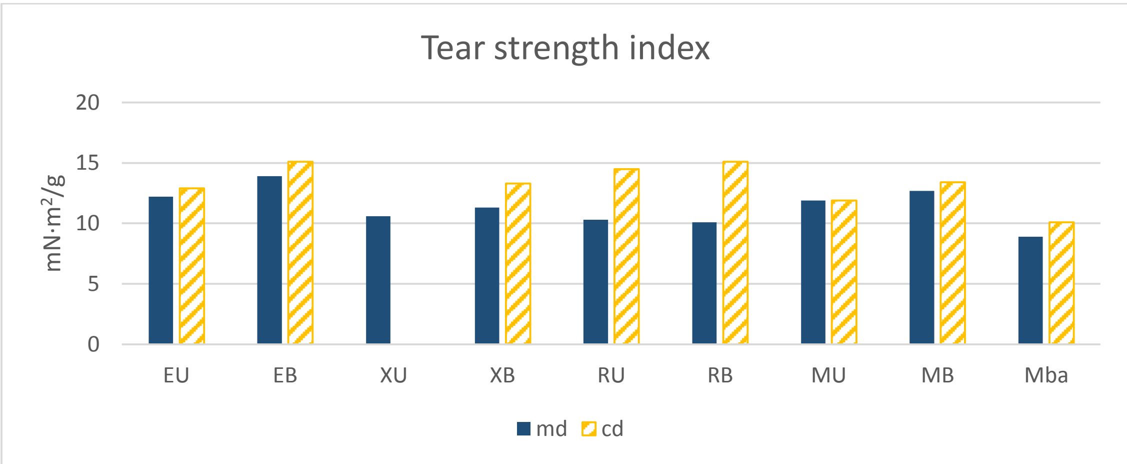


FIGURE 7. Tear strength index of different coffee filter papers. E is Eskimo, X is X-tra, R is Rainbow, M is Melitta, U is unbleached, B is bleached and Ba is bamboo.

The tensile strength was measured in both directions (table 13). The values of the tensile strength for all tested papers, except Eskimo unbleached, in machine direction are higher than in cross direction (figure 8). All results are quite poor. A possible explanation could be the fact that coffee filter paper is not pressed so strong or not pressed at all for avoiding loss of bulk. The linear density of coffee filter paper is low and therefore the tensile strength is low. One more likely explanation could be the presence of curled fibers in paper that also decreases the tensile strength. (KnowPap, h)

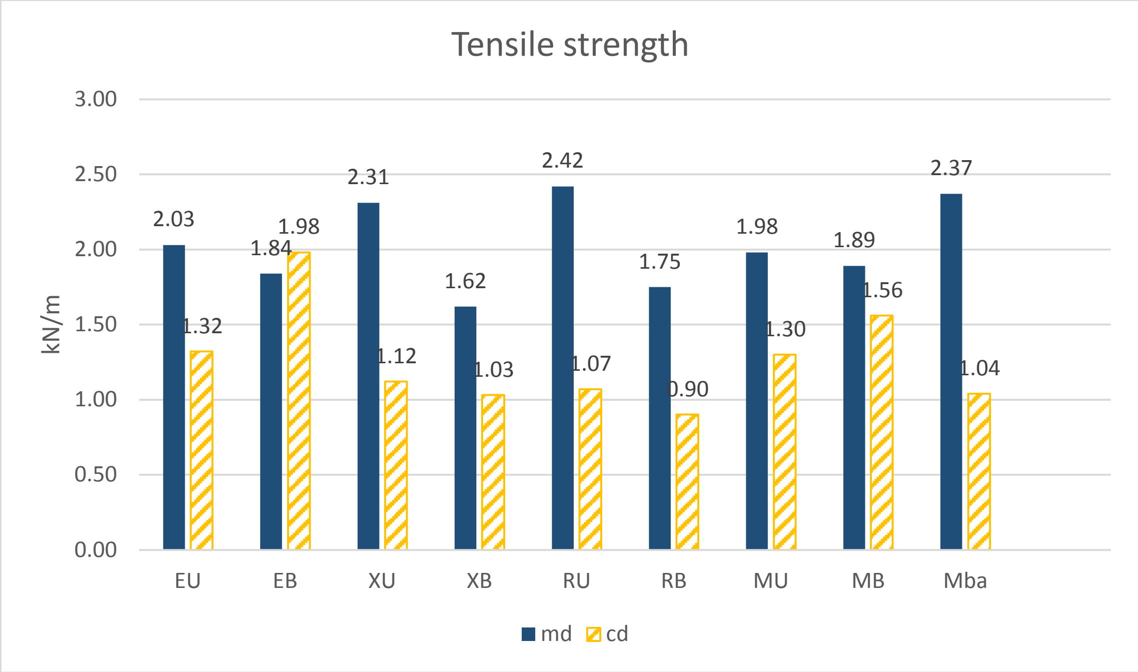


FIGURE 8. Tensile strength of different coffee filter papers. E is Eskimo, X is X-tra, R is Rainbow, M is Melitta, U is unbleached, B is bleached and Ba is bamboo.

Tensile strength index is presented in the figure 9:

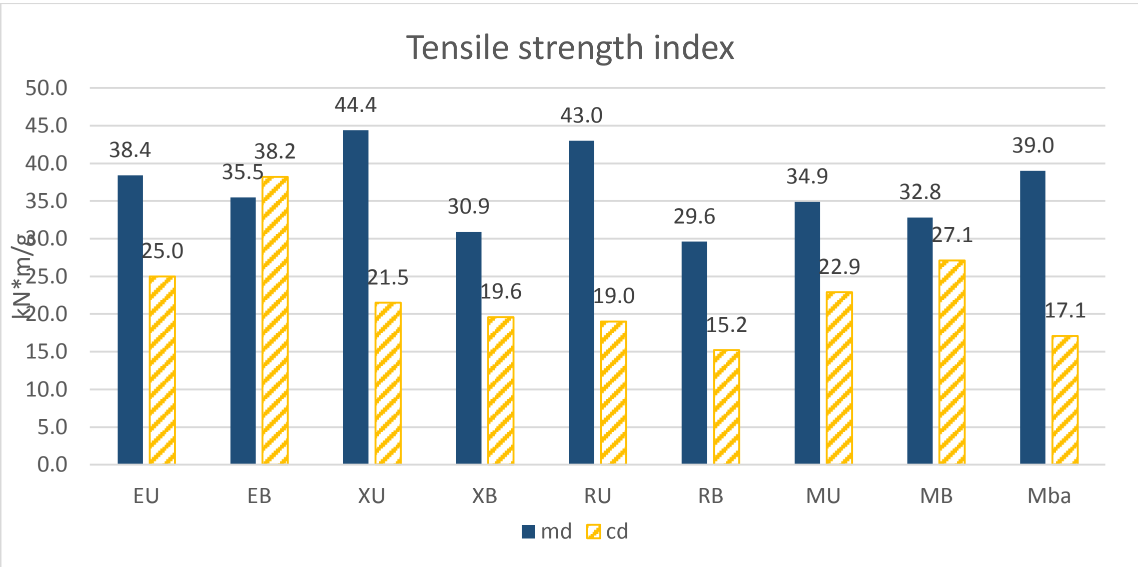


FIGURE 9. Tensile strength index of different coffee filter papers. E is Eskimo, X is X-tra, R is Rainbow, M is Melitta, U is unbleached, B is bleached and Ba is bamboo.

The results of the tensile strength after immersion in water were also obtained for both directions (table 20, figure 10). Only middle part of the test sample was wetted and was tested at once after it.

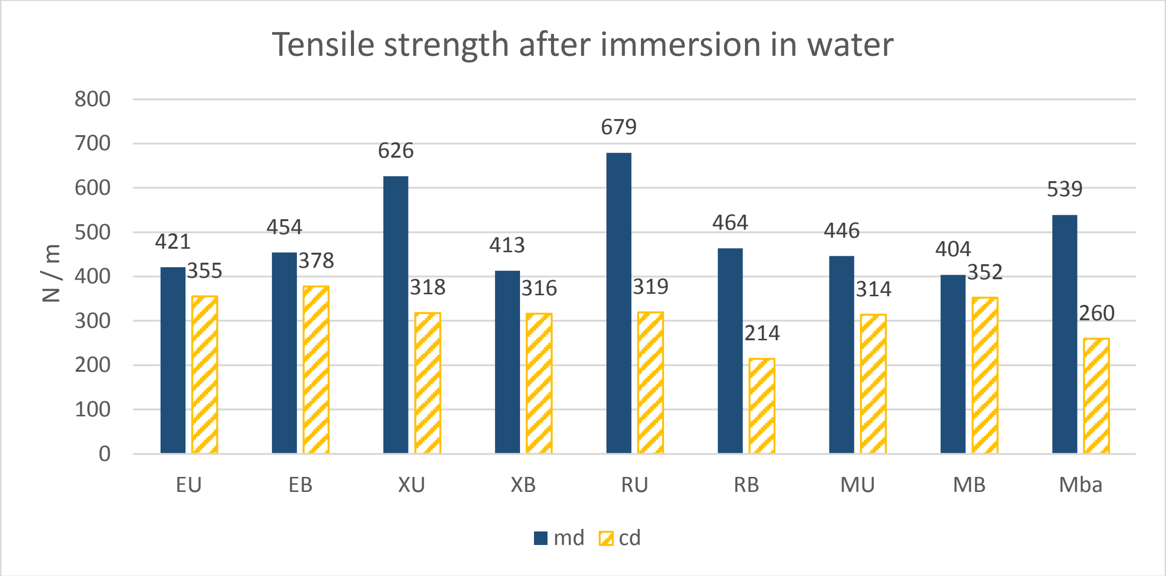


FIGURE 10. Tensile strength after immersion in water of different kind filter papers. E is Eskimo, X is X-tra, R is Rainbow, M is Melitta, U is unbleached, B is bleached and Ba is bamboo.

According to the wet tensile strength results, all values in machine direction are higher than in cross direction, in spite of the fact that dry tensile strength of Eskimo unbleached paper in machine direction was lower than in cross direction. The cheapest papers X-tra and Rainbow as well as Melitta bamboo in machine direction have highest values. Wet tensile strength is seemed to be the most significant value for coffee filter paper, because the usage occurs at wet state.

The tensile strength retention was calculated by using these data (table 21, figure 11). Based on obtained data all papers have high enough tensile strength retention, at least higher than minimum of 15 %, which is mentioned in Scott, Abbott & Trosset (1995). It is interesting that the cheapest papers X-tra and Rainbow showed the higher retention values than the expensive ones.

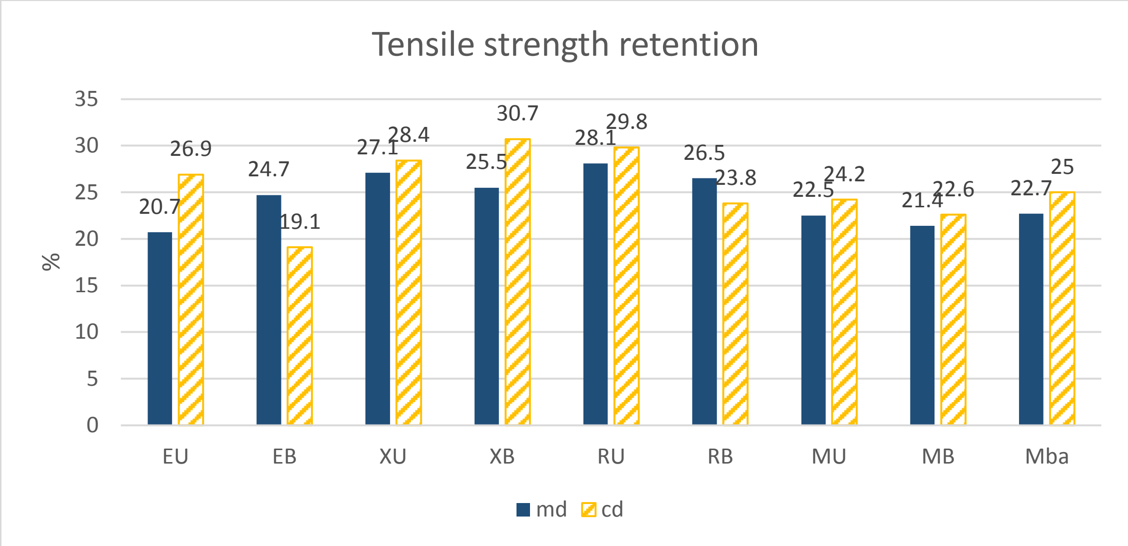


FIGURE 11. Tensile strength retention of different coffee filter papers. E is Eskimo, X is X-tra, R is Rainbow, M is Melitta, U is unbleached, B is bleached and Ba is bamboo.

The bursting strength of dry paper (table 15, figure 12) and paper after immersion in water (table 22, figure 13) were measured from inner side of all filter papers.

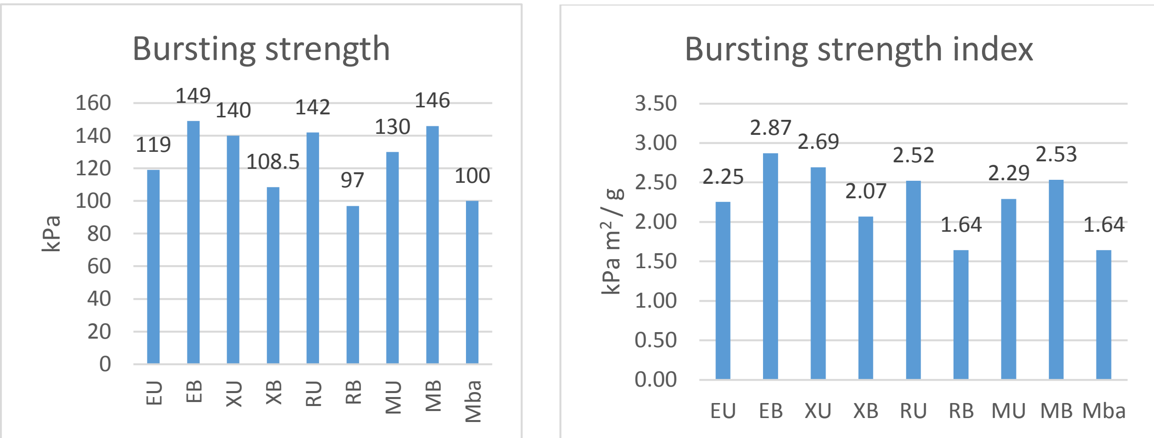


FIGURE 12. Bursting strength and bursting strength index of different coffee filter papers. E is Eskimo, X is X-tra, R is Rainbow, M is Melitta, U is unbleached, B is bleached and Ba is bamboo.

The bursting strength values for the wet paper were lower than 35 kPa, that is why, according to the ISO 3689 two test pieces were bursted together. The results were divided by two. The retention values were calculated and recorded to the table 23. All tested coffee filter papers retain bursting strength in appropriate range from 24 % to 31 %, which is more than 15 %. In this case, also cheap papers demonstrate higher retention than the expensive papers.

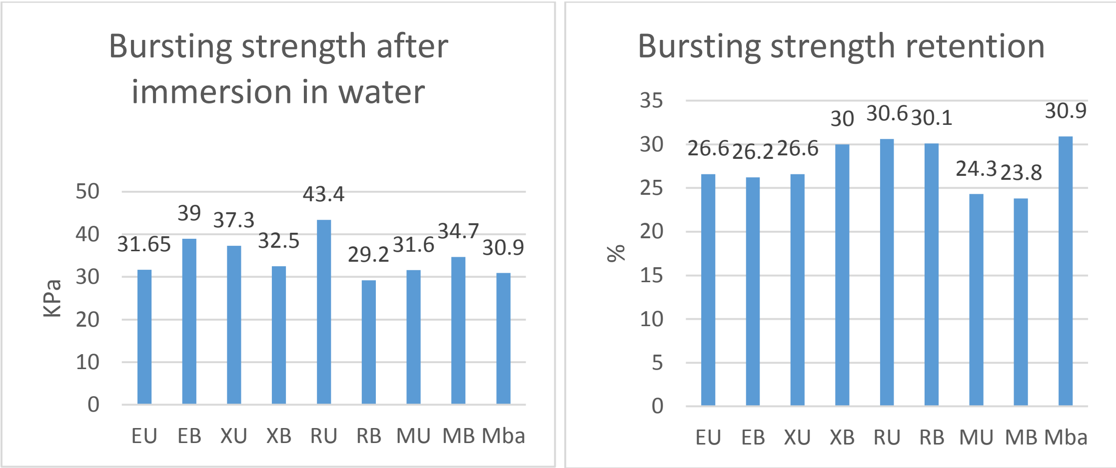
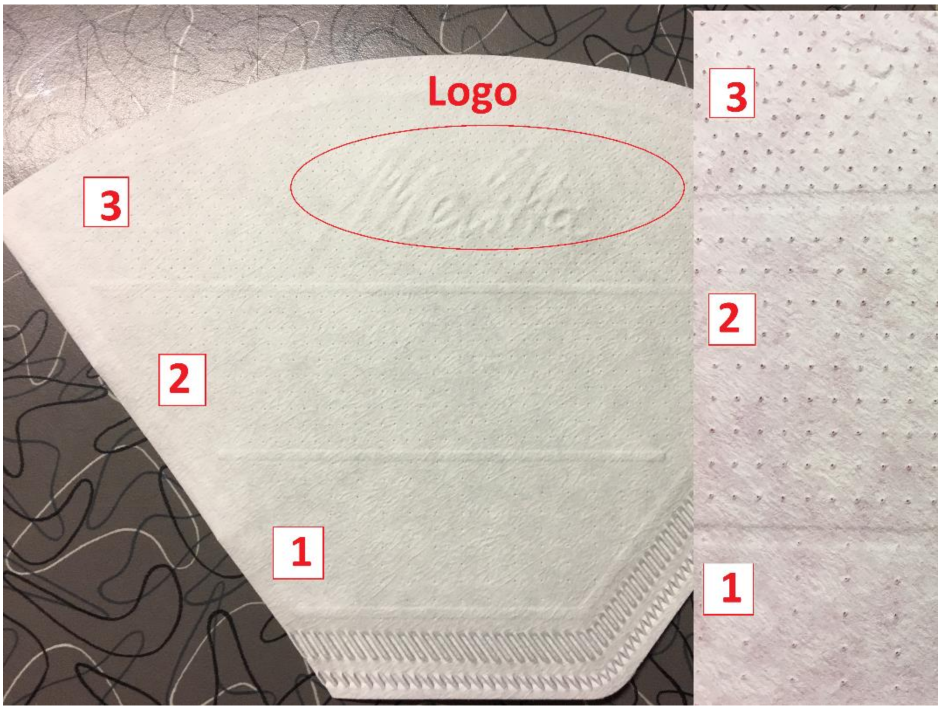


FIGURE 13. Bursting strength after immersion in water and bursting strength retention of different coffee filter papers. E is Eskimo, X is X-tra, R is Rainbow, M is Melitta, U is unbleached, B is bleached and Ba is bamboo.

9.1.3 Surface properties

All filter papers, which were chosen for experimental part of this work have crepe surface. Melitta papers (picture 18) differ from others. The surface of each filter bag of Melitta is divided into three parts. First third goes from constricted part and has perforations. Perforations in the second third has more frequent character. The last third has the most frequent perforations and embossed logo. It can be said that appearance of Melitta papers is more attractive than the others.



PICTURE 18. Melitta bleached coffee filter paper (Photo: Inna Molnar 2016, modified)

Air permeability values are quite low (table 17, figure 5) that is peculiar to filter paper. This property allows to liquid freely and fast pass through the surface of the filter paper during the filtration process.

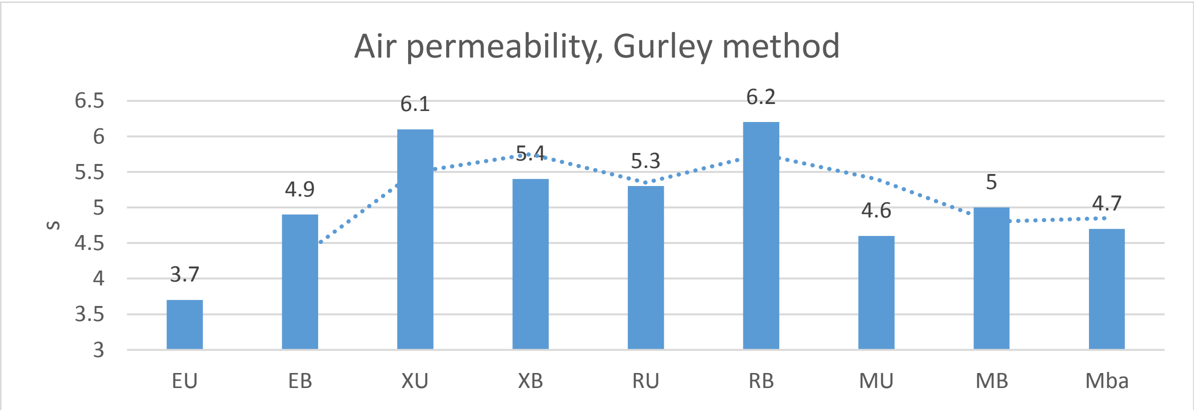


FIGURE 5. Air permeability of different coffee filter papers. E is Eskimo, X is X-tra, R is Rainbow, M is Melitta, U is unbleached, B is bleached and Ba is bamboo.

The results of speed of passing the water through the paper surface are recorded to the table 19. The fastest passing was through the bamboo and Eskimo papers. They have also comparatively low values of air permeability. It has to be said all speed results are near to each other (figure 6) that shows about good drainage ability of all coffee filter papers.

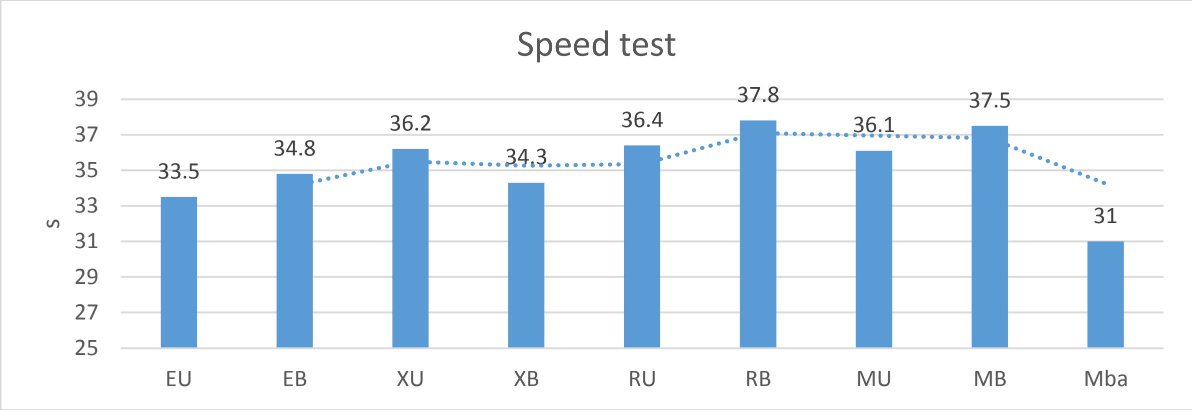


FIGURE 6. Results of the speed test of different coffee filter papers. E is Eskimo, X is X-tra, R is Rainbow, M is Melitta, U is unbleached, B is bleached and Ba is bamboo.

The optimal speed of passing the water through the paper surface is very important aspect. The too fast passing could affect the intensity of the coffee beverage; too low speed can cause stagnation the liquid in the filter.

Roughness was measured only for inner side of the filter, because contact with coffee bins and water occurs from inside. The values of roughness are very high, more than 3000 ml/min (table 18, figure 7). A probable explanation, as it was mentioned earlier, is that coffee filter papers are not exposed to strong pressing during press section and are not calendared.

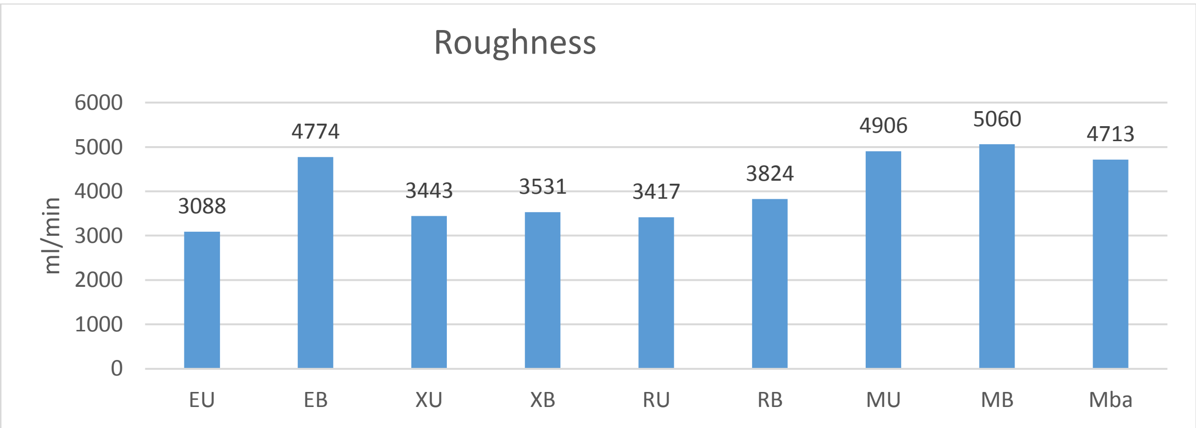
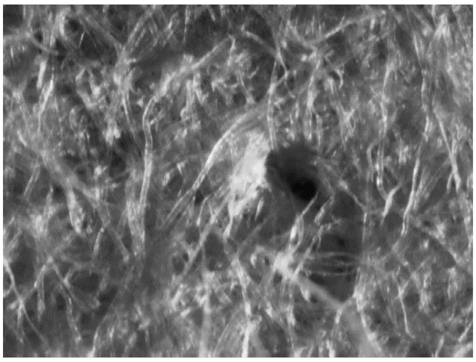


FIGURE 7. Roughness of different coffee filter papers. E is Eskimo, X is X-tra, R is Rainbow, M is Melitta, U is unbleached, B is bleached and Ba is bamboo.

The higher values of roughness for Melitta papers is probably caused, by the perforations as could be seen on the picture 19.



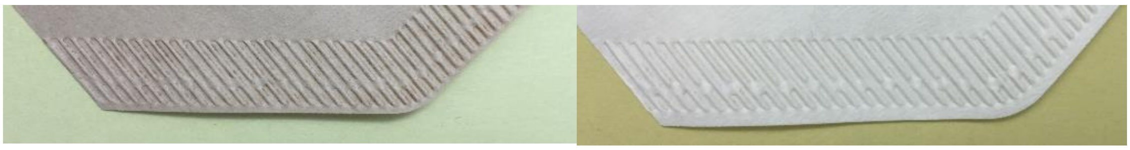
PITURE 19. Perforation whole on the Melitta bleached paper, inner side (photo taken through Microscope)

9.1.4 Seal strength.

Each brand of coffee filter bag has its own design of the seal. All seal types could be seen in the pictures 20 - 24.

PICTURE 20. Eskimo unbleached and bleached (Photo: Inna Molnar 2016)

PICTURE 21. X-tra unbleached and bleached (Photo: Inna Molnar 2016)



PICTURE 22. Rainbow unbleached and bleached (Photo: Inna Molnar 2016)

PICTURE 23. Melitta unbleached and bleached (Photo: Inna Molnar 2016)

PICTURE 24. Melitta bamboo (Photo: Inna Molnar 2016)

The strength of the seals was so weak that could not be define. This is valid for all papers, which were tested. The seal was gradually splitted. Not any pick could be seen on the graphic.

testometric.mp4

Video 1. Seal strength measuring procedure (Video: Inna Molnar 2016).

Paper coffee filters are produced for using in coffeemaker, which is equipped with plastic cone basket for supporting the filter. Therefore, in my opinion, such low strength is justified. In addition, this kind of filter is not heat –sealed, paper is just stamped that is assumed the seal to be weak. The seal strength is quite enough, because filter is located in the supported cup during the process of brewing.

9.2 Coffee tests

Coffee tests include tasting tests and measure of turbidity of the coffee, which was prepared for the tasting tests.

9.2.1 Tasting test

The main idea of the tasting tests was to determine the influence of the coffee filter paper on the beverage quality. On the first day five assessors from seven answered they felt paper flavour in the beverage. For that reason, it was decided to change the cup from paper to ceramic. The answers, which were obtained on the second day, differ from each other so much that there was no possibility to find any systematic results. Evidently, there are too much factors that could affect the beverage quality. These could be quality of the water, presence of scum on the heating element of the coffee maker, the size of the coffee granules (smaller in the bottom of the package). The main aspect is that coffee has very strong odor and flavor by itself and it is very hard to define which factor concretely may have effect. Thus these tests were decided to finish. Assessor's answers could be seen in the appendix 3, tables 24 and 25 for the first and the second days, respectively.

9.2.2 Turbidity test

Turbidity test was carried out two times, directly after tasting test. The values of wood containing papers are higher than the values of bamboo filter paper. According to them it was presumed that bigger amount of organic compounds are remained in coffee after filtration with wood containing papers. Although, I consider these results insufficient.

TABLE 5. The results of turbidity for Melitta coffee filter papers

Turbidity, NTU	Melitta unbleached	Melitta bleached	Melitta bamboo
1st day	96,3	90,2	71,6
2nd day	90,4	91,8	73,0

9.3 Sensory analysis

The aim of the sensory analysis was to define the suitability of usage chosen coffee filter papers for food purposes.

9.3.1 Odour

The number of assessors were nine. The overall tendency of results has been viewed, although some responses were contradictory. Generally, unbleached papers emit more perceptible odor than the bleached papers and the clearest odor was recorded from the bamboo filter. The assessor's responses could be seen in the table 6:

TABLE 6. The answers of assessors for odor test. Number means amount of answers, a is no perceptible odor, b is just perceptible odor, c is weak odor, d is clear odor and e is strong odor.

Paper	a	b	c	d	e
Eskimo unbleached	-	1	3	-	-
Eskimo bleached	2	1	1	-	-
X-tra unbleached	1	2	2	-	-
X-tra bleached	3	2	-	-	-
Rainbow ubleached	1	1	1	1	-
Rainbow bleached	2	2	-	-	-
Melitta unbleached	-	2	2	-	-
Melitta bleached	3	1	-	-	-
Melitta bamboo	-	-	2	1	1
Reference	7	1	1	-	-

9.3.2 Off-flavour

In assessor’s opinion, it was quite hard to determine any extra flavor when tasting chocolate after being in the same reservoir with different coffee filter papers.

The answers (table 7) were not systematic and it was hard to conclude any sustainable approval. Although, slightly is looked the same regularity as it was in the odor test. I think for achieving more clear result the number of assessors should be as much as possible and they should be checked for ability to undergo this kind of sensory analysis before the test.

Most answers show absence of extra flavor or presence of just perceptible or weak flavor. From this, it can be concluded that all papers are suitable for food applications and they will not bring repellent effect during the use. For more meticulous people, I would recommend using bleached coffee filters, because, as it was shown in the results, they emit less odor and flavor.

TABLE 7. The answers of assessors for off - flavor (taint) test. Number means amount of answers, a is no perceptible off - flavor, b is just perceptible off - flavor, c is weak off - flavor, d is clear off - flavor and e is strong off - flavor.

Paper	a	b	c	d	e
Eskimo unbleached	4	4	-	1	-
Eskimo bleached	6	1	1	1	-
X-tra unbleached	3	1	3	1	1
X-tra bleached	4	3	2	-	-
Rainbow unbleached	3	3	2	1	-
Rainbow bleached	5	2	2	-	-
Melitta unbleached	3	4	2	-	-
Melitta bleached	5	3	1	-	-
Melitta bamboo	1	4	2	1	1
Reference	9	-	-	-	-

9.4 Overall conclusion and recommendation

During the experimental part of this work, nine different coffee filter papers were compared by various characteristics. None of the papers has obvious advantages or disadvantages. There is a public opinion that the more expensive ones are better. In case of chosen coffee filter papers, according these tests this is not valid. Based on the results of strength properties, the papers, such as X-tra and Rainbow, which are the cheapest, show better results than the Eskimo and Melitta, which are more expensive.

The big differences between bleached and unbleached papers were not found. According to Knowpap bleaching improves strength properties due to increased alkalinity of the pulp. Generally, this process increases density of the web, bonding strength and wet strength. (KnowPap, l) Nevertheless, obtained results partially contradict this judgment. It was supposed that influence of the bleaching, due to following washing after bleaching, affects results of sensory analysis. It was considered the washing is the reason of less odor and flavor from bleached papers.

Coffee filter paper made of bamboo fibers shows middle numbers of strength properties, while having the biggest grammage. However, results of air permeability and the speed test are in high level. This alternative type of pulp could be helpful for saving natural resources, because of quicker growing of the raw material, but there are some disadvantages. Bamboo has much higher silica content than the wood. Thereby the grass protects itself from the environment. As a result, the high silica content gives scaling problems in the cooking plant and in black liquor evaporation and also difficulties in lime reburning. In addition, in Asia bamboo is considered as a home for around 100 mammal species, over 200 bird species, at least 20 reptiles, and 14 amphibians. Deforestation disturbs the ecosystems. (Global Hemp 2015, Tappsa 2015)

Coffee filter papers, only which are used for cone drip brewing machines, were examined in this thesis work. For this reason, it would be suggested to the next researcher involve to the experiments other types of the coffee filter papers, such as paper for pad or pod filter.

In addition, the Lari's Salomaa opinion that rinsing of the filter bag before use improves beverage quality, would be informative to research. (MTV 2016)

REFERENCES

Air&Water. The Portable Appliance Experts. Read 11.2.2016
http://www.air-n-water.com/coffee-filters-information.htm

CalRecycle. Paper Information and Resources. Chlorine-Free Paper. Read 25.01.2016
http://www.calrecycle.ca.gov/paper/chlorinefree/default.htm

GE Healthcare Life Sciences. Cellulose Filter Papers. Read 2.12.2015
http://www.gelifesciences.com/webapp/wcs/stores/servlet/catalog/en/GELifeSciences-fi/products/AlternativeProductStructure_16153/

Glatfelter. Coffee filter papers. Read 15.12.2015
http://www.glatfelter.com/Files/products/food_beverage/Coffee_Filter_Papers.pdf

Global Hemp. Portal to the hemp community. Bamboo paper is not forest-friendly. Read 6.7.2016
http://www.globalhemp.com/1998/07/bamboo-paper-is-not-forest-friendly.html

Herbert H. Espy 1995.The mechanism of wet-strength development in paper: a review. Tappi Journal, Vol.78 No 4, 90-99

Hutten, I., 2007. Handbook of nonwoven filter media. Elsevier Ltd. First edition. 1, 29, 104-105, 115-116, 294-295

Jaouadi, M., Msehli, S. & Sakli, F. The Indian Textile Journal 09/2007.
http://www.indiantextilejournal.com/articles/FAdetails.asp?id=552

KnowPap. version 17.0. 2015. AEL / Proledge Oy. Restricted availability.

a) Stock preparation. Read 10.12.2015
http://www.knowpap.com.elib.tamk.fi/extranet/english/paper_technology/2_stock_system/1_stock_preparation/1_introduction/frame.htm

b) Wire section. Read 12.12.2015
http://www.knowpap.com.elib.tamk.fi/extranet/english/paperboard_technology/7_wire_section/4_hb_structure/frame.htm

c) Dryer fabrics. Read 21.12.2015
http://www.knowpap.com.elib.tamk.fi/extranet/english/knowpap_system/user_interfaces/maintenance/3_equipment/8_dryer_fabrics/frame.htm

d) Winding. Read 4.3.2016
http://www.knowpap.com.elib.tamk.fi/extranet/english/paper_technology/7_winding/0_introduction/frame.htm

e) Thickness, density and bulk. Read 4.3.2016
http://www.knowpap.com.elib.tamk.fi/extranet/english/paper_board_properties/2_general_properties/3_thickness_and_bulk/frame.htm

f) Fiber orientation. Read 5.3.2016

http://www.knowpap.com.elib.tamk.fi/extranet/english/paper_board_properties/2_general_properties/6_fibre_orientation/frame.htm

g) Tear strength. Read 5.3.2016
http://www.knowpap.com.elib.tamk.fi/extranet/english/paper_board_properties/4_strength_properties/2_tear_strenght/frame.htm

h) Tensile strength. Read 5.3.2016
http://www.knowpap.com.elib.tamk.fi/extranet/english/paper_board_properties/4_strength_properties/1_tensile_strenght/frame.htm

i) Bursting strength. Read 5.3.2016
http://www.knowpap.com.elib.tamk.fi/extranet/english/paper_board_properties/4_strength_properties/3_bursting_strenght/frame.htm

j) Porous structure. Read 5.3.2016
http://www.knowpap.com.elib.tamk.fi/extranet/english/paper_board_properties/5_surface_prop/2_porosity/frame.htm

k) Smoothness and roughness. Read 5.3.2016
http://www.knowpap.com.elib.tamk.fi/extranet/english/paper_board_properties/5_surface_prop/1_rough_smoothness/frame.htm

l) Effects of bleaching on the properties of pulp. Read 4.6.2016
http://www.knowpap.com.elib.tamk.fi/extranet/english/mechanical_pulping/5_bleaching/23_peroxide_impacts/frame.htm

Letherhead Food Research. Sensory evaluation. Read 7.6.2016
https://www.leatherheadfood.com/sensory-evaluation

Mattew Epstein's blog. Finally… A Coffee Maker That Defies True Gravity. Article. Read 13.12.2015.
http://www.matthew-epstein.com/zero-gravity-coffee-maker/

Mattew Epstein's blog. What Type of Coffee Filters Work Best for You? Article Read 13.12.2015
http://www.matthew-epstein.com/different-types-of-coffee-filters/

Meinander, P. 2000. Specialty papers. In book Paulapuro H. (ed.) Paper and Board Grades. Helsinki: Fapet Oy, 111-115.

Melitta. Original coffee filters. Read 13.12.2015
http://www.international.melitta.de/en/Melitta-Original-Coffee-Filters-752,64752.html

Mirsberger P., 2013. Specialty paper machines. In book Holik H. (ed.) Handbook of paper and board Volume 2. Weinheim: Wiley-VCH, 837.

NCA National Coffee Association of U.S.A. About coffee. Read 20.03.2016
http://www.ncausa.org/About-Coffee

Paulig. Preparing coffee. Read 21.03.2016 http://www.paulig.com/en/get-inspired-and-learn/everything-about-coffee/preparing-coffee

Pulp&Paper Resources&Information Site. Paper properties. Read 10.12.2015 http://www.paperonweb.com/paperpro.htm

Specialty Coffee Association of America 2016. Cupping standards. Read 22.03.2016 https://www.scaa.org/?page=resources&d=cupping-standards, https://www.scaa.org/PDF/resources/coffee-to-water-ratio-for-cupping.pdf

Tappsa. Technical Association of the Pulp and Paper Industry of South Africa. Bamboo pulping. Read 6.7.2016 http://www.tappsa.co.za/archive2/Journal_papers/Bamboo_pulping/bamboo_pulping.html

The Indian Textile Journal. Evaluation of real yarn diameter. Article published September, 2007 http://www.indiantextilejournal.com/articles/FAdetails.asp?id=552

YouTube. 2016. Coffee Filter Test - All Filters Are Not Equal. Released 28.7.2009. https://www.youtube.com/watch?v=TODhq1eIUfQ

Voith. Leading technologies for specialty papers. Brochure from 25.03.2014, 27-30 http://voith.com/en/Brochure_2014-03-25_en_leading_technologies_for_specialty_papers.pdf

William E. Scott and James C. Abbott, 1995. Properties of Paper: An Introduction, Second Edition. Atlanta (Ga): TAPPI Press. 19, 55, 75.

APPENDICES

Appendix 1. Results of the tests with dry paper

TABLE 8. Basis weight of different coffee filter papers. E is Eskimo, X is X-tra, R is Rainbow, M is Melitta, U is unbleached, B is bleached and Ba is bamboo

g/m^2	EU	EB	XU	XB	RU	RB	MU	MB	MBa
1	52,2	52,5	50,8	51,2	55,8	59,0	57,3	57,7	61,1
2	52,6	51,8	52,0	53,0	56,8	58,9	55,9	58,3	61,6
3	52,9	51,9	53,2	52,8	56,4	59,6	55,8	57,6	60,7
4	53,3	51,6	52,3	51,6	56,7	59,1	55,9	57,5	60,4
5	53,1	51,5	51,7	53,6	56,5	58,5	56,2	57,3	60,3
6	53,4	51,8	52,0	52,6	56,6	57,8	57,1	56,9	61,4
7	52,6	52,2	52,8	52,8	56,2	59,8	57,1	57,6	60,5
8	52,9	52,1	52,3	51,9	56,3	59,8	57,5	57,4	60,6
9	52,7	51,8	51,6	53,4	56,2	59,2	57,0	57,9	60,7
10	52,6	51,8	51,7	52,4	55,8	59,1	57,3	57,6	60,3
AVE	52,8	51,9	52,0	52,5	56,3	59,1	56,7	57,6	60,8
S.D.	0,37	0,29	0,67	0,77	0,34	0,61	0,68	0,37	0,46

TABLE 9: Thickness of different coffee filter papers. E is Eskimo, X is X-tra, R is Rainbow, M is Melitta, U is unbleached, B is bleached and Ba is bamboo

µm	EU	EB	XU	XB	RU	RB	MU	MB	Mba
1	137,6	142,5	117,0	125,2	135,0	142,9	150,9	152,3	156,4
2	143,2	141,6	124,7	129,9	138,6	140,9	143,6	143,6	161,1
3	141,4	140,9	123,2	121,1	139,9	149,7	148,1	147,4	157,2
4	145,9	141,8	121,9	125,7	140,0	142,8	143,8	145,2	150,2
5	140,9	142,0	131,4	121,2	150,0	140,2	150,7	146,2	149,9
6	141,8	141,7	136,8	132,6	147,6	133,2	146,0	140,6	155,0
7	145,0	141,9	131,0	125,0	138,2	137,1	153,6	159,5	142,7
8	140,2	141,3	127,6	138,0	138,4	140,6	146,6	142,5	161,6
9	136,9	135,4	125,9	118,3	142,2	147,9	156,7	153,2	147,0
10	142,6	137,1	118,3	124,7	144,1	140,4	151,0	154,6	160,7
AVE	141,6	140,6	125,8	126,2	141,4	141,6	149,1	148,5	154,2
S.D.	2,9	2,4	6,1	5,9	4,6	4,8	4,3	6,1	6,5

TABLE 10. Moisture content of different coffee filter papers. E is Eskimo, X is X-tra, R is Rainbow, M is Melitta, U is unbleached, B is bleached and Ba is bamboo

%	EU	EB	XU	XB	RU	RB	MU	MB	Mba
1	6,8	6,7	6,3	5,9	6,2	6,2	6,7	6	6,2
2	6,9	6,5	6,30	6,3	6,2	6,4	6,3	6,2	6,2
3	6,7	6,2	6,40	6,3	6,3	6,2	6,4	6,1	6,2
4	6,8	6,3	6,90	6,3	6,2	6,2	6,4	6,5	6,5
5	6,7	6,4	6,40	6,8	5,7	5,8	6,7	6,2	6,0
6	6,7	6,6	7,20	6,7	6,6	5,8	6,6	6,5	6,3
7	6,2	6,6	7,20	6,6	6	6,3	6,8	6,4	6,0
8	6,8	6,4	6,70	6,9	6,2	5,9	7	6,5	6,0
9	6,5	6,6	6,50	6,9	6,3	6,2	6,7	6,7	6,4
10	6,4	6,5	6,30	6,7	6,8	5,9	6,7	6,3	6,3
AVE	6,7	6,5	6,6	6,5	6,3	6,1	6,6	6,3	6,2
S.D.	0,22	0,15	0,36	0,33	0,30	0,22	0,21	0,22	0,17

TABLE 11. Tear strength of different coffee filter papers. E is Eskimo, X is X-tra, R is Rainbow, M is Melitta, U is unbleached, B is bleached and Ba is bamboo

TABLE 12. Tear strength index of different coffee papers. E is Eskimo, X is X-tra, R is

md mN	EU	EB	XU	XB	RU	RB	MU	MB	Mba
1	697	709	619	564	638	654	634	670	568
2	685	717	619	560	677	544	627	693	540
3	693	701	536	599	521	611	627	755	521
4	631	732	450	587	517	674	713	740	623
5	627	728	540	564	595	576	662	744	489
6	631	674	560	631	599	576	623	705	473
7	607	752	548	681	584	533	662	763	619
8	615	736	572	619	595	517	736	701	548
9	603	709	509	576	493	599	709	771	521
10	634	736	568	565	584	658	728	748	489
AVE	642	719	552	595	580	594	672	729	539
S.D.	36	22	50	40	57	55	45	34	52
cd mN	EU	EB	XU	XB	RU	RB	MU	MB	Mba
1	670	732	-	709	794	833	564	814	666
2	654	767	-	926	689	880	615	670	666
3	685	740	-	572	996	949	728	829	638
4	720	794	-	717	856	744	677	822	525
5	709	744	-	658	841	922	759	720	607
6	670	794	-	701	724	895	646	814	599
7	752	771	-	627	825	1022	728	790	615
8	666	810	-	748	752	841	623	763	638
9	646	880	-	744	767	891	752	755	607
10	654	794	-	576	949	953	658	748	603
AVE	683	783	-	698	819	893	675	773	616
S.D.	34	43	-	103	97	77	65	51	41

Rainbow, M is Melitta, U is unbleached, B is bleached and Ba is bamboo

$mN \cdot m^2/g$	EU	EB	XU	XB	RU	RB	MU	MB	Mba
md	12,2	13,9	10,6	11,3	10,3	10,1	11,9	12,7	8,9
cd	12,9	15,1	-	13,3	14,5	15,1	11,9	13,4	10,1

TABLE 13. Tensile strength of different coffee filter papers. E is Eskimo, X is X-tra, R is Rainbow, M is Melitta, U is unbleached, B is bleached and Ba is bamboo

kN/m	EU	EB	XU	XB	RU	RB	MU	MB	Mba
Md, mean	2,03	1,84	2,31	1,62	2,42	1,75	1,98	1,89	2,37
s.d.	3,79	3,03	6,91	5,52	8,85	6,51	6,55	4,87	0,36
Cd, mean	1,32	1,98	1,12	1,03	1,07	0,90	1,30	1,56	1,04
s.d.	2,87	4,23	9,63	4,50	7,22	5,00	5,00	3,87	7,94

TABLE 14. Tensile strength index of different coffee filter papers. E is Eskimo, X is X-tra, R is Rainbow, M is Melitta, U is unbleached, B is bleached and Ba is bamboo

Nm/g	EU	EB	XU	XB	RU	RB	MU	MB	Mba
md	2,03	1,84	2,31	1,62	2,42	1,75	1,98	1,89	2,37
c.d.	3,79	3,03	6,91	5,52	8,85	6,51	6,55	4,87	0,36

TABLE 15. Bursting strength of different coffee filter papers. E is Eskimo, X is X-tra, R is Rainbow, M is Melitta, U is unbleached, B is bleached and Ba is bamboo

kPa	EU	EB	XU	XB	RU	RB	MU	MB	Mba
1	126	145	152	120	180	79	137	135	109
2	130	132	125	127	106	118	157	154	101
3	106	155	130	99	154	110	139	157	106
4	137	160	141	115	101	97	120	118	109
5	111	158	122	91	138	97	127	139	86
6	114	146	180	108	150	83	136	129	110
7	112	150	136,00	117	149	85	111	169	94
8	119	149	131,00	117	138	86	137	114	65
9	118	134	154,00	88	165	108	117	171	101
10	118	160	126,00	103	135	108	119	169	116
AVE	119,0	149,0	140,0	108,5	142,0	97,0	130,0	146,0	100
S.D.	9,00	10,00	18,00	12,95	24,00	14,00	14,00	21,00	15

TABLE 16. Bursting strength index of different coffee filter papers. E is Eskimo, X is X-tra, R is Rainbow, M is Melitta, U is unbleached, B is bleached and Ba is bamboo

	EU	EB	XU	XB	RU	RB	MU	MB	Mba
index, kPa*g/m^2	2,25	2,87	2,69	2,07	2,52	1,64	2,29	2,53	1,64

TABLE 17. Air permeability of different coffee filter papers. E is Eskimo, X is X-tra, R is Rainbow, M is Melitta, U is unbleached, B is bleached and Ba is bamboo

s	EU	EB	XU	XB	RU	RB	MU	MB	Mba
1	4	5	6	5	5	7	5	5	5
2	4	5	7	5	5	6	5	5	5
3	3	5	6	5	6	6	5	5	5
4	4	5	6	6	6	7	4	5	4
5	4	4	6	5	5	7	4	5	4
6	4	5	6	5	5	6	4	5	5
7	4	5	7	6	5	5	5	5	5
8	3	5	6	5	6	5	5	5	5
9	4	5	5	6	5	7	5	5	5
10	3	5	6	6	5	6	4	5	4
AVE	3,7	4,9	6,1	5,4	5,3	6,2	4,6	5,0	4,7
S.D.	0,48	0,32	0,57	0,52	0,48	0,79	0,52	0,00	0,48

TABLE 18. Roughness of different coffee filter papers. E is Eskimo, X is X-tra, R is Rainbow, M is Melitta, U is unbleached, B is bleached and Ba is bamboo

ml/min	EU	EB	XU	XB	RU	RB	MU	MB	Mba
1	3124	5114	3231	3823	3730	4093	5093	4891	4358
2	2815	4481	3314	3221	4024	3616	5638	6000	4847
3	3669	4629	3632	3761	3349	3872	5153	4740	4726
4	2996	4828	3446	3646	3659	3587	5308	4629	4823
5	2865	5141	3408	3028	3989	4194	4459	5259	4249
6	3288	4848	3682	3801	3910	3676	4262	5164	4724
7	3210	4033	3643	4107	3682	3670	4248	4892	4943
8	3085	4926	3313	3320	3673	3376	6000	5051	4590
9	2899	5241	3212	3198	4074	4148	4502	4855	5153
10	2933	4499	3549	3403	3499	4011	4393	5122	5278
AVE	3088	4774	3443	3531	3417	3824	4906	5060	4713
S.D.	255,2	369,9	175,5	345,9	236,9	278,3	620,4	383,6	281,4

TABLE 19. Speed test. E is Eskimo, X is X-tra, R is Rainbow, M is Melitta, U is unbleached, B is bleached and Ba is bamboo

s	EU	EB	XU	XB	RU	RB	MU	MB	Mba
1	32,34	33,34	36,84	34,56	34,03	38,97	35,84	31,68	34,10
2	40,94	35,44	36,53	38,03	37,03	30,56	44,11	43,57	32,03
3	32,93	35,28	37,28	33,31	35,81	40,25	34,43	37,50	30,35
4	31,50	35,94	35,31	36,09	31,28	33,97	35,03	36,59	29,53
5	32,53	33,15	37,94	31,81	42,03	37,97	33,13	36,97	30,47
6	33,41	32,37	33,22	36,66	32,56	43,34	37,47	40,57	33,60
7	32,99	37,5	35,66	34,75	37,43	39,53	32,57	35,97	29,47
8	34,15	34,38	36,78	30,72	33,05	36,48	35,62	40,11	29,88
9	31,90	34,25	37,13	32,10	41,42	40,11	34,14	38,13	30,07
10	32,03	36,34	34,95	34,88	39,85	37,08	38,77	34,05	30,13
AVE	33,5	34,8	36,2	34,3	36,4	37,8	36,1	37,5	31,0
S.D.	2,74	1,59	1,39	2,31	3,78	3,59	3,38	3,38	1,68

Appendix 2. Results of the tests with wet paper

TABLE 20. Tensile strength after immersion in water of different coffee filter papers. E is Eskimo, X is X-tra, R is Rainbow, M is Melitta, U is unbleached, B is bleached and Ba is bamboo

	EU	EB	XU	XB	RU	RB	MU	MB	Mba
Md, mean, N/m	421	454	626	413	679	464	446	404	539
s.d., N/m	3,9	3,54	7,26	10,5	9,10	5,97	5,36	8,29	5,62
Cd, mean, N/m	355	378	318	316	319	214	314	352	260
s.d., N/m	4,16	4,36	9,58	7,58	9,76	6,45	6,11	6,25	7,59

TABLE 21. Tensile strength retention of different coffee filter papers. E is Eskimo, X is X-tra, R is Rainbow, M is Melitta, U is unbleached, B is bleached and Ba is bamboo

	EU	EB	XU	XB	RU	RB	MU	MB	Mba
md, %	20,7	24,7	27,1	25,5	28,1	26,5	22,5	21,4	22,7
cd, %	26,9	19,1	28,4	30,7	29,8	23,8	24,2	22,6	25,0

TABLE 22. Bursting strength after immersion in water of different coffee filter papers. E is Eskimo, X is X-tra, R is Rainbow, M is Melitta, U is unbleached, B is bleached and Ba is bamboo

kPa	EU	EB	XU	XB	RU	RB	MU	MB	Mba
1	35,5	47	31	33,5	39	26	27,5	34	31
2	31,5	47	30	37	48,5	30,5	37,5	35,5	32
3	30	41,5	26	26	33	26	31	35	31,5
4	31	47	32	26	34	38,5	34	39	35
5	30	43,5	52	26	32	26	29,5	36,5	28,5
6	31,5	47	52,5	34	41	32,5	34,5	36,5	28,5
7	29	27,5	30,5	37	44,5	26	31,5	29	30,5
8	33,5	37,5	31	41	51	26	33,5	35	28,5
9	32,5	26	32,5	26	50,5	34	30	32,5	32,5
10	32	26	38	38,5	60,5	26	27	34	31
AVE	31,65	39	37,3	32,5	43,4	29,2	31,6	34,7	30,9
S.D.	1,89	9,16	12,63	5,97	9,31	4,52	3,30	2,67	2,07

TABLE 23. Bursting strength retention of different coffee filter papers. E is Eskimo, X is X-tra, R is Rainbow, M is Melitta, U is unbleached, B is bleached and Ba is bamboo

	EU	EB	XU	XB	RU	RB	MU	MB	Mba
Retention, %	26,6	26,2	26,6	30,0	30,6	30,1	24,3	23,8	30,9

Appendix 3. Results of the coffee tasting tests

TABLE 24. The answers of assessors for coffee tasting test on the first day. Number means amount of answers.

Characteristics		Melitta bleached	Melitta unbleached	Melitta bamboo
Main	Intermediate			
Aroma	Chocolate	-	1	-
	Earth	1	-	-
	Flowers	1	1	-
	Fruits	-	-	1
	Herbs	-	-	1
	Nuts	-	-	1
	Paper	5	5	4
Body	Thickness or	4	4	2
	Thinness	3	3	5
Mouthfeel	Creamy	2	2	3
	Oily	-	-	1
	Buttery	1	-	-
	Silty	1	2	-
	Watery	3	3	3
Acidity	Low	2	1	1
	Medium	1	2	1
	High	4	4	5
Flavor	Nuts	-	-	1
	Earth	1	-	-
	Fruits	1	2	1
	Paper	5	5	5
Finish	Short	4	4	4
	Long	3	3	3
Sediment	Yes	-	-	-
	No	7	7	7

TABLE 25. The answers of assessors for coffee tasting test on the second day. Number means amount of answers.

Characteristics		Melitta bleached	Melitta unbleached	Melitta bamboo
Main	Intermediate			
Aroma	Chocolate	-	1	1
	Earth	-	-	2
	Flowers	1	1	-
	Fruits	3	2	-
	Herbs	-	1	1
	Nuts	1	-	1
Body	Thickness or	2	3	2
	Thinness	3	2	3
Mouthfeel	Creamy	1	-	1
	Oily	-	2	-
	Buttery	1	1	1
	Silty	2	1	1
	Watery	1	1	2
Acidity	Low	2	3	3
	Medium	-	-	-
	High	3	2	2
Flavor	Nuts	1	-	-
	Earth	1	1	-
	Fruits	2	2	1
	Spices	1	-	1
	Caramel	-	1	1
	Flowers	-	-	1
	Paper	-	-	1
Finish	Short	1	2	3
	Long	4	3	2
Sediment	Yes	-	-	-
	No	5	5	5