T.C.
YEDITEPE UNIVERSITY
INSTITUTE OF HEALTH SICENCES
DEPARTMENT OF PHARMACEUTICAL TECHNOLOGY
MASTER'S PROGRAM IN COSMETOLOGY

DETERMINING THE BENEFITS OF NATURAL OILS USED IN HAIRCARE PRODUCTS

MASTER THESIS

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BSc. Pharm

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DETERMINING THE BENEFITS OF NATURAL OILS USED IN HAIRCARE PRODUCTS

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DECLARATION

I declare that this thesis is my own work and that according to the best of my belief and knowledge, it does not contain previously published material nor material that is written by another person nor material that had been accepted for other degree award except where due acknowledgment has been made in the text.

14/06/2019

Essam Turkmani

To the most influencing people in my life… To my father and mother

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ABBREVIATIONS

CMC	cell membrane complex
18-MEA	18-methyl eicosanoic acid
IF	intermediate filaments
IFAP	inter-fibrillar associated proteins
KAP	keratin associated proteins
HS	high sulfur proteins
UHS	ultra high sulfur proteins
HT	high tyrosine proteins
HGT	high glycine tyrosine proteins
SLS	sodium lauryl sulfate
DSC	differential scanning calorimetry
(T_g)	glass transition temperature
LPV	Virgin hair treated with linseed oil
LPB1	Bleached x1 hair treated with linseed oil
CCV	Virgin hair treated with coconut oil
CCB1	Bleached x1 hair treated with coconut oil
VH	Virgin Hair
BH1	Bleached once hair
BH4	Bleached x4 hair
BH7	Bleached x7 hair

ABSTRACT

Turkmani, E. (2019). "Determining the Benefits of Natural Oils Used in Haircare Products". Yeditepe University, Institute of Health Sciences, Department of Pharmaceutical Technology. Master Thesis. Istanbul

This study aims to investigate the penetration abilities of some natural oils into human hair and the how these oils affect hair properties. Also, the effect of repeated hair bleaching was monitored and the ability of the studied oils to restore the desired hair properties was studied. Mineral oil was used as a negative, non-penetrating, control and coconut oil as a positive, penetrating, control. Other oils used were linseed oil, almond oil and baobab oil. Hair tress used was obtained from a Turkish supplier as the same person's virgin hair and the swatches were prepared according to the test requirements in house with the help of a hair wig maker. Virgin hair swatches were bleached in the laboratory. The penetration of the oils into the hair cortex was investigated by using fluorescence microscopy after marking the oils with an oil soluble probe, nile red. Cross-sections of hair filaments were made by cutting the hair vax blocks by microtome. Penetration studies were conducted for the five oils on both virgin hair and bleached hair swatches.

The effects of the oils on physical properties of the virgin and bleached hair were studied by measuring the stress at break point; tensile strength of the hair fibers. Combing forces were also measured to evaluate the effects of using the oils on the ease of combing of hair switches. Repeated combing and grooming test was also conducted to evaluate the effect of each oil on the reduction of hair breakage under harsh circumstances.

Differential scanning calorimetry was also used to monitor the structural changes and chemical damage caused to hair by bleaching and the effects of penetrating oils vs. non-penetrating oils on restoring the hair properties. And finally, the effect of oils on hair porosity and how it affects water loss from the hair was studied. Fluorescence microscopy results showed that linseed oil and almond oil were able to penetrate into virgin hair, whereas baobab oil was not. It was also noticed that when hair was bleached, all the oils were able to penetrate into the cortex, meaning that bleaching caused some real damage to the hair cuticle cells allowing the oils to get through the cuticle layer and reached into

the cortex. It was also noted that the further the hair was bleached, the weaker and more prone to breakage it was getting, and application of oils onto the hair had favorable effects in almost all cases studied. Tensile strength results also showed that penetrable oils improved stress at break points for both virgin and bleached hair, whereas non-penetrable oils did not have a noticeable improvement on the stress at break point for virgin hair, but it did have an effect on bleached hair.

Keywords: Hair, haircare, natural oils, effect of oils on hair

ÖZET

Turkmani, E. (2019), "Saç Bakım Ürünlerinde Kullanılan Doğal Yağların Yararları". Yeditepe Üniversitesi Sağlık Bilimleri Enistitüsü, Farmasotik Teknoloji ABD, Master Tezi, İstanbul

Bu çalışmanın amacı, bazı doğal yağların insan saçı içine nüfuz etme yeteneklerini ve bu yağların saç özelliklerini nasıl etkilediğini incelemektir. Ayrıca, tekrarlanan saç ağartma işleminin etkisi ve yağların istenen saç özelliklerini geri kazandırma yeteneği de araştırılmıştır. Mineral yağ, negatif, penetre olmayan, kontrol yağ olarak belirlenirken, hindistan cevizi yağı, pozitif, penetre olan, kontrol yağ olarak kullanılmıştır. Kullanılan diğer yağlar keten tohumu yağı, badem yağı ve baobab yağıdır. Aynı kişiye ait işlem görmemiş saç tutamı bir Türk tedarikçiden temin edilmiş ve testler için saç tutamları test gereksinimlerine göre bir saç peruğu üreticisinin yardımı ile tarafımızdan hazırlanmıştır. İşlem görmemiş (virgin) saç örneklerine ağartma işlemi laboratuvarda uygulanmıştır Yağların saç korteksine penetrasyonu, yağda çözünen bir boya olan Nil kırmızısı ile yağların işaretlenmesi yoluyla floresan mikroskopisi kullanılarak incelenmiştir. Saç tellerinin vaks blokları içinde mikrotom cihazı ile enine kesitlri alınmıştır. Işlem görmemiş ve ağartılmış saç örnekleri ile kullanılan beş yağ için penetrasyon çalışmaları yapılmıştır.

Yağların, işlem görmemiş ve ağartılmış saçların fiziksel özellikleri üzerindeki etkileri, saç liflerinin gerilme kuvveti ve kopma noktasındaki direnci ölçülerek incelenmiştir. Yağ kullanımının saç tutamlarını tarama kolaylığı üzerindeki etkilerini değerlendirmek için tarama kuvvetleri de ölçülmüştür. Her bir yağın sert koşullarda saç kırılmasının azaltılmasındaki etkisini değerlendirmek için tekrarlanan tarama ve kişisel bakım (grooming) testi de yapılmıştır.

Diferansiyel taramalı kalorimetri, ağartma işlemi uygulanan saçtaki yapısal değişiklikleri, kimyasal hasarı ve penetre eden ve etmeyen yağların saçların özelliklerini geri kazandırmadaki etkilerini izlemek için kullanılmıştır. Son olarak, yağların saç gözenekliliği üzerindeki etkisi ve saçtan su kaybını nasıl etkilediği incelenmiştir. Floresan mikroskopisi sonuçları, keten tohumu yağı ve badem yağının işlenmemiş saça penetre oabildiğini, boabab yağının ise penetre olamadığını göstermiştir. Ayrıca, saç

ağartıldığında, bütün yağların kortekse penetre olduğu görülmüştür, yani saç ağartma işlemi saç kütikül hücrelerinde bazı gerçek hasarlara neden olarak, yağın kütikül katmanından geçmesine ve kortekse ulaşmasına izin vermektedir. Ayrıca saçın daha fazla kez ağartılması sonucunda zayıfladığı ve kırılmaya daha yatkın hale geldiği, ve saça yağ uygulanmasının, incelenen hemen hemen tüm vakalarda olumlu etkileri olduğu da kaydedilmiştir. Ayrıca gerilme kuvveti testi sonuçları, penetre olabilen yağların hem işlem görmemiş hem de ağartılmış saçlar için kırılma noktalarındaki stresi arttırdıklarını, oysa penetre olamayan yağların bu konuda işlem görmemiş saç örneklerinde farkedidilir bir iyileşme sağlamadıklarını, ancak ağartılmış saçlar üzerinde bir etkiye sahip olduklarını göstermiştir.

Anahtar Kelimeler: Saç, Saç bakım, doğal yağalar, doğal yağların saç üzerine etkisi

1 INTRODUCTION

1.1 GENERAL INFORMATION

Hair fibers consist a considerable part of the surface coating of most mammals [1]. Human hair is a highly organized cylindrical appendage that contains keratin and grows from big cavities that extend from the top of the skin into the dermis through the stratum corneum and the epidermis, those large cavities are named hair follicles [1, 2], (figure 1-1). Secondary components that contribute to the total mass of hair are lipids and melanin pigments [3]. Hair is classified as a dead substance and it is alive only when it is infused in the scalp. When the fiber appears on the skin it becomes a dead substance [4].

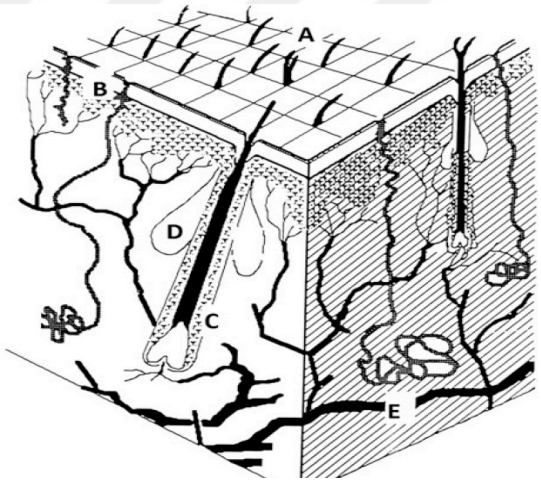


Figure 1-1: A section of human skin clarifying a hair fiber in its follicle as it emerges through the skin [2].

A. Stratum Corneum B. Epidermis

C. Pilosebaceous Unit D. Sebaceous Gland

E. Blood Vessel

1.2 GENERAL HAIR STRUCTURE

Morphologically, a totally developed hair shaft contains three or occasionally four different structures or units. At the outermost is the cuticle, which is classified to be the protective structure of the hair. This protective layer surrounds the cortex, which contains the main section of the mass of the hair fiber. Near the center of the fiber, coarse hairs generally

contain porous region called the medulla. The last important structure is the cell membrane complex (CMC) which is considered to be the glue that holds the cells to each other [2], (figure 1-2).

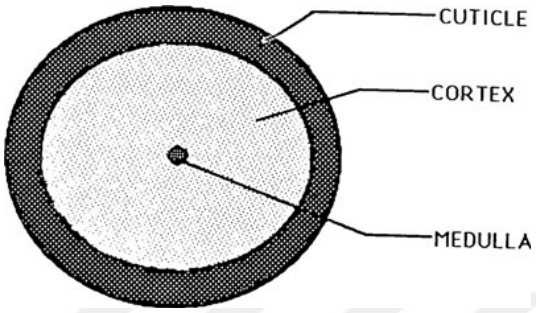


Figure1-2: Schematic diagram of a cross-section of a human hair fiber [2]

1.2.1 The Cuticle

The cuticle is composed of flat overlapping scales (cells). These cells are linked at the root end and they slope down the tip end of the hair fiber. The differential friction effect in hair is subject to the shape and the specific coordination of the cuticle cells [2, 5].The cuticle's volume ratio is almost 14% of total hair volume [6], and the main component of it is protein [7]. Each cuticle cell is relatively 0.5 µm in thickness and 45-60µm in length, and on average, seven to eight thin sheets of cuticle layers are superposed at the hair surface[8, 9] (figure 1-3). The cuticle is the chemically resistant region in the hair shaft and it protects the cortex against chemical attacks [1].

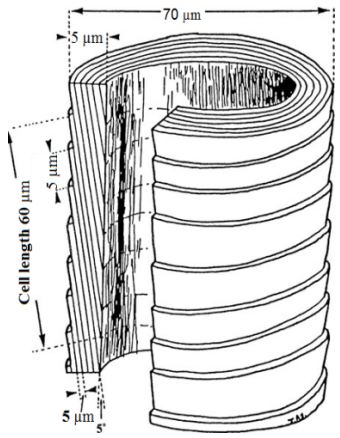


Figure 1-3: The dimensions and layering of the human hair cuticle illustrated by a schematic diagram[9]

1.2.1.1 Layers of the Cuticle

1.2.1.1.1 The Epicuticle

Epicuticle is considered to be the outermost layer of the cuticle. It is a thin protein reach membrane which is covered with a lipid layer, of which 18-methyl eicosanoic acid (18-MEA) constitute the largest portion which is strongly connected to the lipid layer that is called the F-layer [1]. This protein-lipid bound grant a substantive hydrophobic surface to the cuticle [2]. The thickness of the epicuticle layer ranges between 10-14 nm. In terms of the conditioning of the hair fibers, from the polymers deposition point of view, the epicuticle is considered the most important part of the cuticle [10].

1.2.1.1.2 Layer A

A highly resistant cross-linked structure that ranges between 50-100 nm in thickness and contains >30% cysteine [1]. The protein cross links in this layer have a great influence on the physical and chemical resistance of the hair fiber which protects the hair against both chemical and mechanical attacks [11].

1.2.1.1.3 The Exocuticle

This layer lays down beneath Layer A and is sometimes called Layer B. It is, as Layer A, cystine rich (~15-20%) and it is rigid physically but still less intensively than Layer A [1, 2]. The exocuticle thickness is highly variable with an average of about 150 nm making almost 55% of the cuticle area [9, 12].

1.2.1.1.4 The Endocuticle

The endocuticle lays underneath the exocuticle with low content of cystine (~3%) [9]. A portion of the endocuticle is also considered as epicuticle or “epicuticle-like” matter, but it is way softer than the upper layers, and there are some clues that the endocuticle swells with water, causing an intensification of the apex of the surface stages of the fiber, and this demonstrate why the friction coefficient is lower in dry hair than in wet one. The thickness of the endocuticle varies from about 50-300 nm with an average of about 150 nm [13, 14].

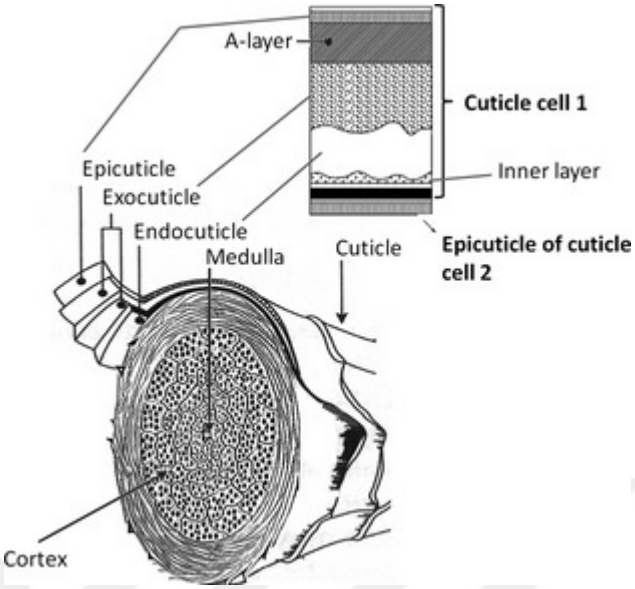


Figure1-4: Schematic cross-section of a hair fiber showing medulla, cortex and cuticle cell layers [15]

1.2.2 The Cortex

The cortex makes up the main share of the fiber mass (70-90%) [2]. Following the cuticle, the cortex has cells occupied by cross links of cystine and separated by the CMC. The cortex also contains keratin proteins and structural lipids [16].

1.2.2.1 Cortical Cells

Although significant difference has been reported in their size and shape, the human hair fibers cortical cells are usually 1-6 μm in thickness and nearly 50-100 μm in length [17]. Three types of cortical cells were found in diverse portions in hair among different ethics [18], these are:

1.2.2.1.1 Orthocortical Cells

This type of cells contains lower matrix substance among the intermediate filaments and also has less sulfur content [18].

1.2.2.1.2 Paracortical Cells

These cells have higher sulfur content than the orthocortical cells, they have smooth curved edges and they are smaller in diameter [19].

1.2.2.1.3 Mesocortical Cells

This type of cells comprise an intermediate content of cystine [20].

1.2.2.2 Macrofibrils

The spindle-shaped macrofibrils make up the main portion among the cortical cells and one macrofibril is somewhere between 0.1-0.4 μm in diameter and is made of intermediate filaments named microfibrils, which are considered to be very structured fibrillar units, embedded into a cystine rich, fewer organized construction called the matrix [21, 22].

1.2.2.2.1 Microfibrils

Microfibrils are sub-filamentous structures contained in the macrofibrils. They are also known as intermediate filaments (IF) as they are originated from intermediate filament keratins or proteins [21]. Each IF is approximately 75Å in diameter and is described as a crystalline fibrous protein which is primarily constituted of the alpha-helical proteins, in coiled coil formation, of a low cystine disulfide content [23, 24].

1.2.2.2.2 Matrix

Even though it has some structural organization, the matrix is usually known as the amorphous region [2]. In human hair fibers, the matrix makes up the prime organizational subunit of the cortex, and from a mechanical point of view, it does not really look like a highly cross-linked polymer, but a lightly cross-linked gel. Matrix proteins are known as "inter-fibrillar associated proteins" (IFAP) or "keratin associated proteins" (KAP's)[21].

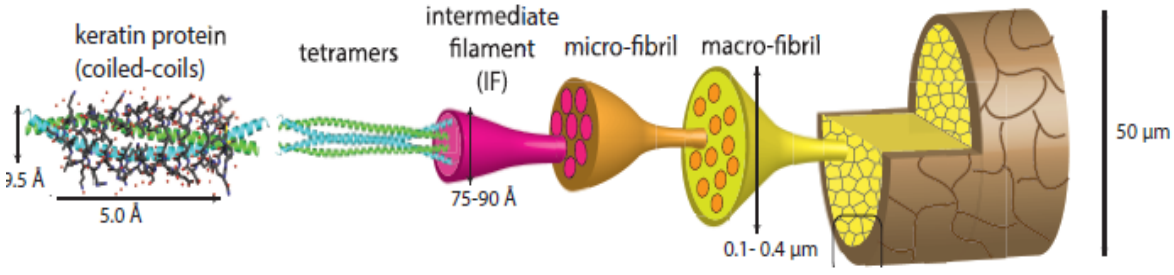


Figure1-5: Schematic of hair fiber showing the components of the cortex [16]

1.2.3 The Medulla

Medulla is not always found in human hair, and when present, it constitutes only a small portion of the fiber mass [7]. It is located at the center of the hair fiber and it mainly consists of lipids and proteins. The medulla might be continuous by the fiber axis, or it may be discontinuous and in some cases a double medulla may be found, and in others, divided medulla might be seen [25] (Figure 1-6). At high magnification power, medullary cells look sphere-shaped and empty from inside, these cells are connected together via a CMC type material. There is a direct proportion relationship between the diameter of the hair fiber and the amount of the medulla, which means, the finer the hair fiber is, the less the chance of the presence of the medulla in hair, and if present, the less percentage of the medulla mass. This is why children fine hair usually does not have a medulla, but adults' coarser hair normally contains a medulla. From cosmetic science point of view, medulla is not of a great importance as it negligibly affects the mechanical and chemical properties of human hair fibers[26, 27].

Some studies suggest that most of the hair of the scalp does not have a medulla, and that the diameter of the medulla was realized to be considerably greater in pubic hair when compared to the hair of the scalp and axillary [28, 29].

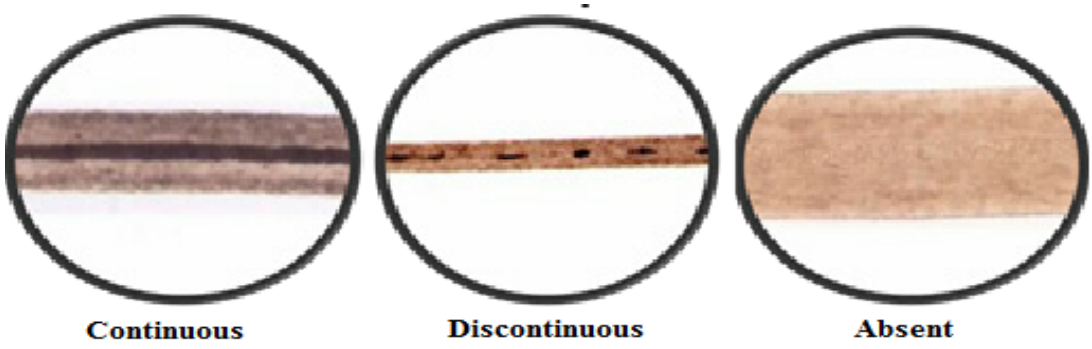


Figure1-6: Three types of the medulla; continuous, discontinuous, and absent [30]

1.2.4 Cell Membrane Complex

The cell membrane complex (CMC) is the structure that binds hair cells to each other. It is made of adhesive material and cell membranes which connects the cortical cells and the cuticle cells in keratin fibers [31]. It consists of a 15 nm thick proteinous delta layer located at the center surrounded by two lipid layers known as beta layers, each of these beta layers has a thickness of approximately 5 nm. CMC is considered to be the route for preferential distribution of molecules into the hair fibers [32, 33]

According to its place of existence, CMC can be classified into three different types; cuticle – cortex CMC exemplifying the CMC at the cortex cuticle borderline, cortex – cortex CMC exemplifying the CMC among cortical cells, and cuticle – cuticle CMC exemplifying the CMC among cuticle cells [31] (Figure 1-7).

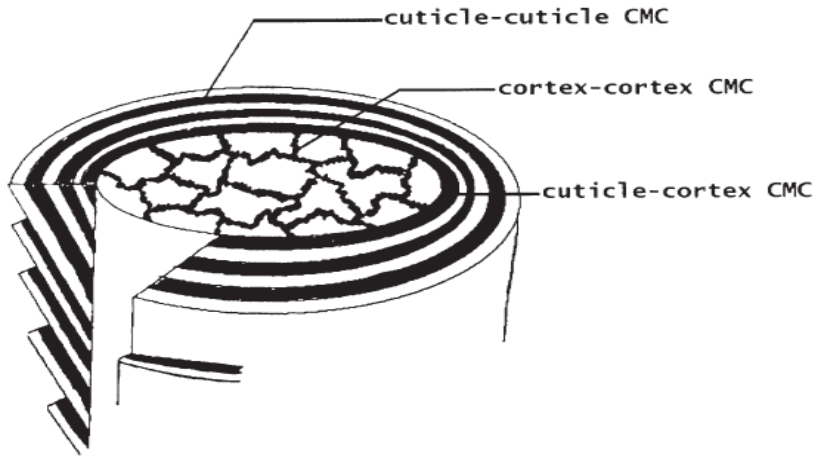


Figure1-7: Schematic of the location of the three types of CMC [31]

1.2.4.1 Cuticle - Cuticle CMC

The cuticle-cuticle CMC has an approximate thickness of 30 nm [1]. One of the most important lipid components on the cuticle – cuticle CMC is covalently bound 18-MEA which is found in the upper beta layer and some clues show that the fatty CMC are structured in monolayer and that most of them are covalently bound to the keratin fiber surface [16, 31, 34] (Figure 1-8).

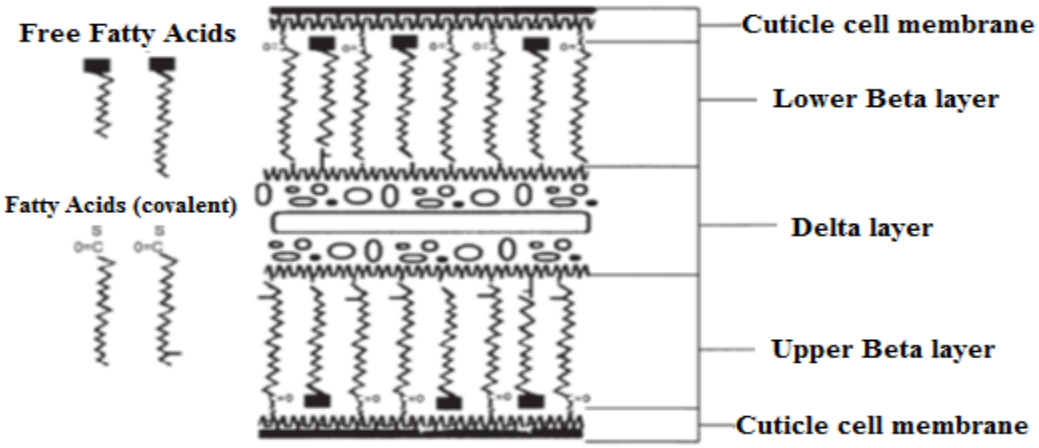


Figure1-8: Schematic of the cuticle-cuticle CMC [31]

1.2.4.2 Cortex – Cortex CMC

Unlike the cuticle – cuticle CMC, the beta layer of the cortex – cortex CMC does not contain covalently bound 18-MEA, whereas most of the fatty acids in the cortex – cortex CMC are non-covalently bound such as ceramides, cholesterol sulfate, and cholesterol [31]. These non-covalently bound fatty acids are structured in bilayers rather than in a monolayer [7, 32] (Figure 1-9).

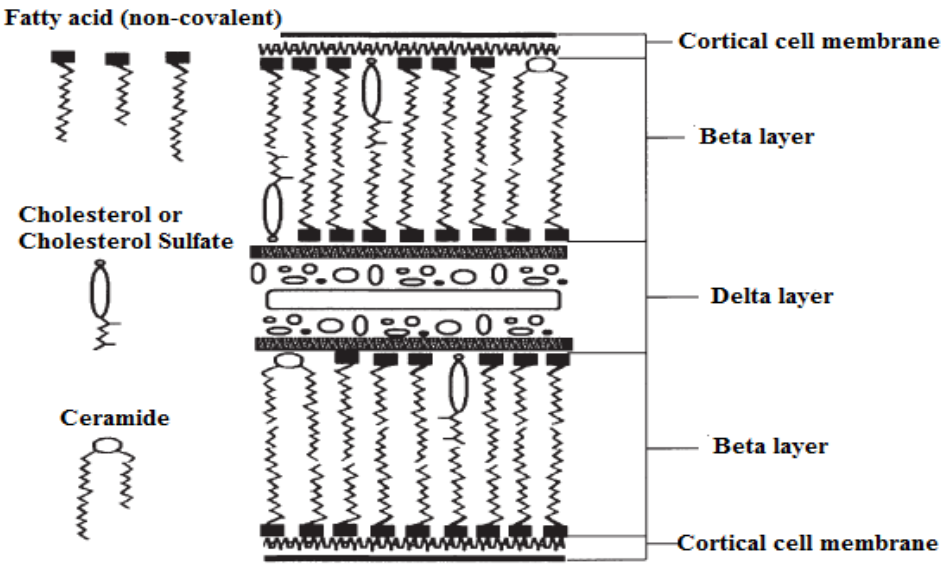


Figure 1-9: Schematic of the cortex - cortex CMC [31]

1.2.4.3 Cuticle – Cortex CMC

As the cuticle – cortex CMC connects the cuticle and the cortical cells together, it is rational for it to have the properties of both the cuticle – cuticle CMC and the cortex – cortex CMC [7]. The beta layer alongside the cuticle is attached to the cuticle via covalent bonds and is a monolayer, whereas the beta layer alongside the cortex has non-covalent bonds and is organized in bilayers [31] (Figure 1-10).

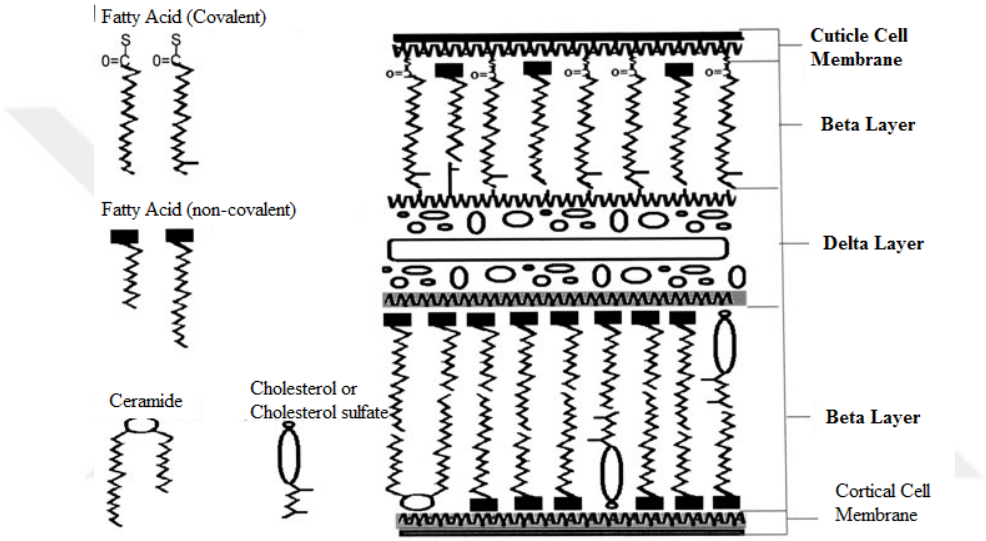


Figure 1-10: Schematic of cuticle - cortex CMC [31]

1.3 HAIR GROWTH CYCLE

Hair development and growth is in fact a cyclic dynamic process which is harmonized by many cytokines and hormones and directly related to many factors as where hair is growing, individual's age, dietary habits, or even environmental variations as day length [2]. Despite the previously mentioned factors, human hair grows in three distinct phases and has particular mutual structural characteristics and these three phases of hair fibers growing are called anagen or growth phase, catagen or transitional phase, and telogen or resting phase [28] (Figure 1-11). The anagen stage is the active growth stage and is characterized by strong metabolic activity in the bulb of the hair which can last for 2-6 years in scalp hair. The catagen or transitional stage starts when the anagen phase ends and during this stage, the metabolic activity slows down and the bulb's base drifts upward in the skin in the direction of the epidermal surface. This stage lasts for only a few weeks and is characterized by a special

structure called “the club hair”. After the catagen stage comes the telogen stage at which the hair goes into a resting stage. At this stage hair growing completely stops and the base of the bulb atrophies to a point at which it come close to the level of the sebaceous canal and when this stage comes to an end, hair falls. Few weeks later hair follicle return to the anagen stage and a new hair growth cycles starts again [35].

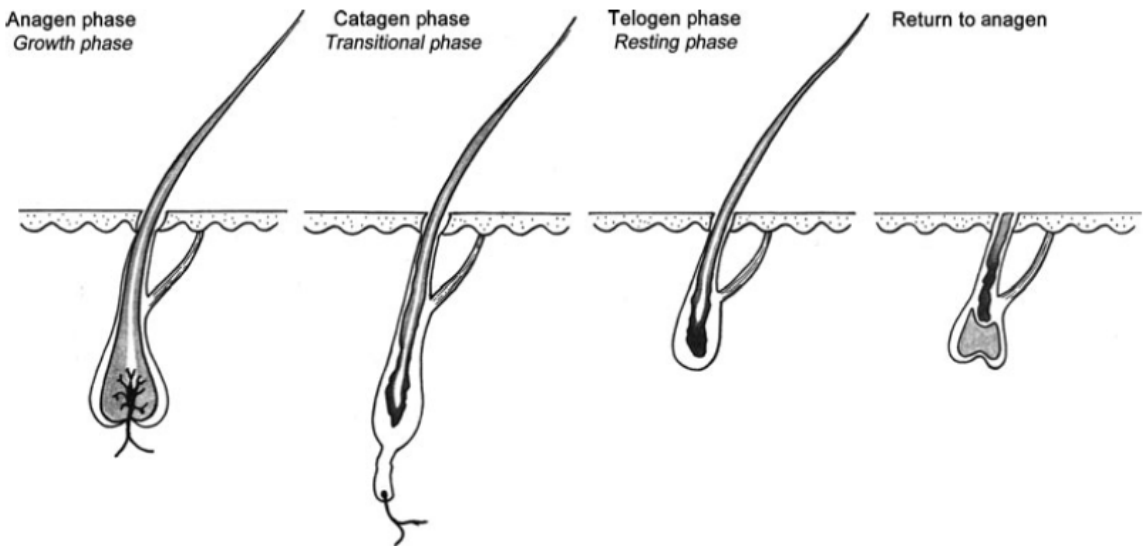


Figure 1-11: Schematic of the different phases of hair growth cycle [28]

1.4 HAIR CHEMICAL COMPOSITION

Human hair is a complicated matter that is composed of many different structural constituents, and every constituent consists of many diverse chemical classes. The main chemicals that constitute the hair are proteins, lipids, water, trace elements, and pigments [36].

1.4.1 Proteins in Human Hair

Human hair contains approximately 65% to 95% proteins, and this percentage differs depending upon the moisture content of the hair which can goes up to 32% and the major protein fractions that are found in human hair are [37, 38]:

- Keratin associated proteins (KAP), which were also known as intermediate filament associated proteins.
- Intermediate filament proteins (IF), which are known now as keratins.
- High sulfur proteins (HS).
- Ultra-high sulfur proteins (UHS).
- High tyrosine proteins (HT).
- High glycine tyrosine proteins (HGT).

The major protein components among these are keratin proteins which are part of the fibrous structural proteins family and are complex natural compounds having a heterogeneous morphological arrangement [39]. Keratins are considered as the main building block of hair and wool fibers, and are part of structural material of human nails and skin as well [39]. As hair grows, keratin which is located within the cells develops into more crystalline state as cells differentiate, allowing hair fibers to grow, as these keratinized cells make up an enormously well-arranged material which main task is to protect hair against various conditions that might damage the hair as chemical treatments, UV, and physical attacks and constrains [40]. Human hair keratins amino acid composition is characteristically unlike the other keratins, since the major difference between keratin types rise up from the glycine content which is 11.6% in stratum corneum keratin and 5.6% in human hair keratin, and the cysteine content which is 2.9% in stratum corneum keratin and 7.6% in human hair keratin [41]. However, amino acid composition of hair may be affected by several factors such as gender, where cystine content of male hair is higher than it is in female hair, while weathering and cosmetic treatments can also significantly affect the amino acid content of hair [40]; for example, due to weathering, cystine and cysteine level is notably less in the tip end of the hair than it is in the root end .

1.4.2 Lipids in Human Hair

Lipids in hair constitute 1 – 9% of total hair weight and they are originated from two primary sources; the hair matrix cells and the sebaceous glands which are found all over the body where hair exists and excrete their lipids onto hair and skin through a tight opening of the follicle [42]. The output of the sebaceous glands is very low prior to puberty but it

increases at the adulthood through the youthful years and into the fourth decade where it starts to lower again [36, 43].

Table 1-1: Lipids in human hair [43, 44]

Type of lipid	**Percentage of lipid**
Ceramides	1.2
Cholesterol	5.2
Hydrocarbon	9.7
Total fatty acids	59.3
Triglycerides	2.0
Wax ester	19.8
Squalene	2.8
Total	100

Wertz and Downing reported the percentages of the internal covalently bound fatty acids of human hair as 41% 18-MEA, 18% palmitic acid, 7% stearic acid, 4% oleic acid, 21% small fractions of fatty acids between C16 and C20, 9% uncharacterized [45].

1.4.3 Water in Human Hair

Water is considered as a fundamental constituent of human hair that the amount of moisture of the keratin fibers is directly related to the state of dryness and the relative humidity of the atmosphere, and this directly affects both physical and cosmetic properties of human hair, which are greatly influenced by the moisture content of the hair [36]. Hair's capability of absorbing water is relatively high, though; this capability is affected by several factors such as the lipid content of the hair as well as the pH level. When absorbing water, hair swells, however, hair swelling is anisotropic, as the length of hair fiber increases roughly 2%, whereas the diameter of the fiber rises to more than 15% when relative humidity changes from 0% to 100% [46].

1.4.4 Trace Elements in Human Hair

Hair contains very low mineral content, usually less than 1% [36]. Trace elements in human hair are of a noticeable importance in both cosmetic science and forensic science, the following are among the elements that are reported in human hair: Ca, Mg, Sr, B, Al, Na, K, Zn, Cu, Mn, Fe, Ag, Au, Hg, As, Pb, Sb, Ti, W, V, Mo, I, P, and Se [47].

1.4.5 Pigments in Human Hair

Pigments in hair are produced by the melanin producing cells which are called the melanocytes which are stored in spherical or ovoid pigment containing granules that are called melanosomes, and then, they are transported into the hair fiber cells, the keratinocytes [48]. The size of the pigment granules usually ranges between 0.4 – 1 μm whereas the larger pigment granules are usually found in black hair and the smaller granules are found in blonde hair. The sizes of granules along with the type of the pigment mainly determine the color of the hair and there are two types of main pigments in human hair, the eumelanins (the brown – black melanins), and the pheomelanins (the red melanins) which are less common [49-51].

1.5 EFFECTS OF DIFFERENT COSMETICS ON HAIR

Hair appearance is a crucial component of human appearance with major social and psychological effects in everyday life and human hair is considered to be one of the easy modifiable physical features in term of shape, length, or color. Years from now and until our current day, many cosmetics have been used in order to clean the hair and change its appearance and style [40]. All through human history, a lot of people have wanted to modify the way their hair appears as it was a way to distinguish the social position, for example, Ramesses II, the third Egyptian pharaoh, used henna to change hair color to red, and in the ancient Greece, an ointment composed of yellow flower petals and pollen was mixed with a rinse of potassium solution and used to bleach hair [52].

1.5.1 Effects of Shampoo on Hair

The main goal of using shampoo is to remove dirt and oil from the hair fibers surface and from the scalp. Usually, commercial shampoos may as well have extra components to control dandruff and condition hair [53]. Because of the variety of the purposes of these hair care products, they comprise a list of ingredients with numerous effects on the hair, although shampoos usually contain a primary and a secondary surfactant for comprehensive cleaning, a viscosity increasing agent, a solvent, conditioning agents, pH adjuster and other non-essential components such as fragrance and color for commercial appeal [54]. Since shampoo removes dirt and oils at the surface level, most of the shampoo interactions can be expected to occur at the very first few layers of the cuticle, the cortex will only be affected if the

damage to the cuticle is extensive and the cortex has been exposed [53]. There is evidence that shampooing can result in hair damage in this case; however, the effect is thought to be limited to the cuticle level; for instance, abrasive action of the shampooing process can damage the keratin and non-keratinous structures at the surface of the hair [16]. Studies have shown that using shampoo once can extract approximately 50% of total extractable lipids in hair cuticula, and that 70–90% of total lipids can be extracted with repeated shampooing [53]. The cell membrane complex at the cuticle level contains covalently bounded lipids attached to a proteinous cell membrane. At the hair's outer surface, free lipids are removed during shampooing. Internal lipids found deeper within the hair shaft are not affected to the same extent as the surface lipids. Internal lipids can travel to the surface layers via the process of diffusion after repeated shampooing [54].

1.5.2 Hair Dyeing and Bleaching

The main object of bleaching human hair is to lighten the hair, and this purpose is mainly achieved by oxidation by using oxidative agents such as alkaline hydrogen peroxide [55].

1.5.2.1 Compositions of Hair Bleaches

Hair bleaches mainly contain hydrogen peroxide, ammonia, and salts of persulfate to enhance their effectiveness and speed up the process of bleaching [56].

1.5.2.2 Mechanism of Hair Bleaching

Hair bleaching with chemicals such as alkaline peroxide and alkaline peroxide-persulfate depends on a destructive oxidation of melanin pigments. It leads to the degradation of thioester groups that bind 18-MEA to the hair surface, and due to the harsh reaction conditions needed for devastation of the chromophoric groups of the pigments in human hair, simultaneous side reactions are normal to occur with hair proteins such as degradation of thioester bonds at the hair surface and between cuticle cells as well as the disulfide bonds of the cuticle proteins and the cortical matrix [57, 58].

1.5.2.3 Effects of Hair Bleaching

Hair chemical bleaching deteriorates the cell membrane complex by oxidizing the thioester bonds between cuticle cells, also remove the hydrophobic surface barrier by attacking 18-MEA thioester binding groups [55]. Bleaches also attacks the hair regions that are rich in cystine such as the A-layer and exocuticle in the cuticle cells and thereby oxidize cystine, all of which cause the cell membrane complex to collapse and breakdown the cuticle and cortex constituents and eventually vanishes proteins in these regions [59]. Bleached hair is also prone to detachment of cuticle layers and establishment of holes in the cortex especially during every day grooming and weathering processes such as repeated shampooing, exposure to sun, drying with blow dryer, brushing and combing, all of which can lead to weakening of the hair and deterioration in its feeling and appearance [55, 59].

1.5.2.4 Hair Dyeing

Using hair dye products to change hair color is a frequent habit especially among women. However, the way hair dyes act on hair might lead to real hair damage at the structural level [60, 61]. Hair dyes can be categorized into two main groups, according to the dye type, oxidative or non-oxidative, and according to durability of the color after applying the dye on hair as temporary, semi-permanent, demi-permanent, and permanent [62]. The major distinction between dyes is the capability of reaching the cortex and staying there permanently or not reaching the cortex but staying on the cuticle exterior and be removable after like 15 shampoos cycles. In order for the dye to penetrate through the cuticle into the cortex, the pH of the medium must be alkaline in order to open the scales. Usually, permanent dyes use ammonia to increase the pH and If the product is claimed to be ammonia-free, ethanolamine is used for the purpose of increasing pH. Both substances, ammonia and ethanolamine, remove 18-MEA, which grants hydrophobicity to hair fibers, causing cuticle damage and making hair more hydrophilic [60].

1.5.3 Effects of Permanent Waving on Hair

Permanent waving is the process of converting straight hair into curled hair using a chemical process which comprises the breaking and restructuring of the disulfide bonds within hair using reducing agents such as thioglycolates and bisulfites. Alkaline reductive

solutions are used to lift the scales of the cuticle so that the reducing agent can effectively diffuse into the cortex and the reduction infuses throughout the cuticle and into the outer layers of the cortex [16]. In a second step, the hair fibers are shaped into the preferred curl and held using curlers. During this time, molecular reorganization occurs in the cuticle layers, as well as in the outer levels of the cortex. Lastly, the fibers are neutralized with an oxidizing agent such as hydrogen peroxide [63]. The damage caused to hair due to permanent waving is well known as the use of hydrogen peroxide in the oxidation step increases surface damage and decreases the stiffness of the fiber. Additionally, the permanent waving process was found to extract internal lipids from the cell membrane complex of the fiber, as a significant decrease in polar internal lipids after permanent waving treatment was noted. Furthermore, the permanent waving process converts the hydrophobic hair surface to a more hydrophilic one [16].

1.5.4 Hair Straightening

Many people with curly hair try to find ways to straighten their hair. In order for this to happen, disulfide bonds of hair must be relaxed and reformed and this process requires an alkaline agent with a high viscosity two phase emulsion [64]. There are two main groups of agents used to straighten hair, first group include reductive agents such as sulfites and mercaptans which are generally selective so that they don't disturb the entire protein, but instead they cleave the disulfide bonds so that they can be when the process ends [15]. If a permanent hair straightening is desired, a hot iron may be used to provoke enough additional stress. The other group of agents used for hair straightening is alkaline agents that contain hydroxides with a pH higher than 9.0. This group of agents is less selective, cleaving disulfide bonds with a permanent fission. Alkaline medium stimulates swelling of the hair causing cuticle scales to open and thus, allowing the alkaline agent to deeply penetrate into the cortex where a rearrangement of disulfide bridges may happen as the hydroxyl ions disorder hair keratins disulfide bonds. This alkali hair treatment includes lanthionization reaction in which a part of the amino acid cystine is substituted for lanthionine [15]. Hair straightening using this procedure is more efficient, though it causes harm to hair fiber integrity because this disulfide bonds into lanthionine bonds conversion is permanent and it affects almost one-third of the disulfide bonds [15, 65].

1.5.5 Blow Drying of Hair

Using hair dryer to dry hair causes hair damage at a surface level and when this is repeated it can cause several breaks and fractures on hair cuticle and it might as well lead to damage the hair ultrastructure and change hair color. Hair damage increases as temperature increases, however, unless the cuticle is totally damaged and removed so the cortex becomes exposed, this damage is always limited to hair surface and cuticle and does not exceed it to the cortex. Anyhow, using hair dryer at a distance of 15 cm while moving continually was found to cause less damage than naturally drying hair [66].

1.5.6 Sun Exposure and UV Light

Sun exposure is considered to be one of the most common reasons behind structural damage of hair shaft. Excessive sun exposition might lead to hair dryness and loss of color, stiffness and brittleness of hair, decreased luster and rough texture, as well as decreased hair strength [67]. Increased exposition to sun also leads to removing hair surface lipids and cuticular layers including split end formation due to cuticular layers rupture and detachment by the effect of UVB which causes loss of hair surface proteins, whereas UVA can overcome the cuticle and penetrate into the hair cortex and is responsible for hair color changes and pigment degradation. Melanin helps protecting hair against adverse UV radiations therefore protecting hair proteins explaining why hair with higher amount of pigmented granules loose less protein when exposed to UV radiation [67].

1.6 COSMETICS USED TO IMPROVE HAIR PROERPTIES

Hair is considered of a very high importance for self-confidence and it has an extremely significant role in our appearance and self-concept. Hair appearance reveals person’s personality and if hair damage might have both social and psychological consequences. This is why hair cosmetics and care products are widely used by almost everyone [67].

1.6.1 Hair Conditioners

The main reasons for using hair conditioners are to decrease friction, untangle the hair, improve hair combability and reduce frizz, re-establish hair hydrophobicity, add shine to hair, and enhance smoothness and manageability [53]. The main mechanism that

conditioners act by is decreasing negative charge of hair fibers and by so neutralizing the charge of hair fibers mainly by adding positively charged ions on hair surface, also friction is reduced by conditioning ingredients that smoothens the cuticle layers against the longitudinal axis of hair fiber. Light is more reflected of hair surface on cuticle layers when they are flattened, improving hair color and shine and adding softness to the hair. Hair conditioners also provide protection to the cortex by sealing cuticle gaps that expose the cortex, defending it against damage, although depending on the molecular weight of the conditioner molecules, they can either stay on the surface of the cuticle or penetrate into the hair cortex. Conditioners are mainly oil in water emulsions holding a positive charge. The main ingredients of a conditioner are polymers, oils or waxes, preservatives, cationic agents, aesthetic agents, and additives as well as bridging agents may also be combined to cationic molecules to enhance hydrophobic ingredients adsorption to the hair. UV filters can also be used in a conditioner to protect color [53, 63]. One among the most used conditioning agents is silicone. Silicones are inert, heat resistance, rubber like polymers. Silicon dioxide is the starting material to produce silicones. The most widely used silicone in hair conditioners is dimethicone and other silicones commonly used are anionic silicones, aminosilicones, siloxysilicates, polysiloxane polymers, and others, which all act differently on hair. Dimethicones are hydrophobic substances, that's why they adsorb better on the root of the hair fiber rather than the tip and on virgin hair rather than bleached hair. Dimethicones protect hair against harsh actions, whereas siloxysilicates increase volume of hair, while polysiloxane polymers set lifted cuticle layers back to its place preventing damage caused by heat [68, 69].

1.6.2 Natural Oils

Many natural oils have been used all around the world as hair treatments. The usage of natural oils for hair care is increasingly growing either as a prewash or by including in commercial hair care products as shampoos and conditioners [70]. Using oils on hair is an ancient practice especially in African and Asian countries. Using oils for hair care might be beneficial to both hair shaft and hair follicle. First of all, oil hydrophobicity has a significant effect on protecting hair against damage, secondly, the lubrication of hair surface provided by oil is considered to be the initial point to protect hair from harsh damage caused by

grooming. The hygral fatigue, which is repeated swelling and deswelling, is a main factor to damage hair fibers and is caused by the penetration of low molecular weight surfactants present in shampoos such as sodium lauryl sulfate (SLS) into the hair fiber lifting the cuticle and causing swelling of hair. Applying oil to hair increases hair hydrophobicity and decreases water absorption by hair, causing hair fiber swelling to reduce. On the hair follicle level, SLS and other low molecular weight surfactants which can penetrate and reach into the hair follicle may obstruct the follicular structures adhesion, causing a loosening of the hair fiber in the follicular cavity, and eventually causing hair loss. However, using oil on hair regularly, and if the oil is reaching and getting into the hair follicle, the gap between the follicular wall and the hair fiber is filled and by so the surfactant solution can no more penetrate into the follicle, eliminating follicular damage and protecting hair [69, 71, 72]. Oil penetration through the hair cuticle and into hair cortex is desirable for extensive benefits, as the health of the cortex determines the mechanical properties of the hair fiber. Using coconut oil on hair either as prewash or post-wash treatment reduces protein loss from hair whether it is healthy or damaged hair. On the other hand, sunflower oil and mineral oil do not have the same effect. The difference between the effects of the previous oils is probably due to the difference in each oil composition. Coconut oil which is mainly a triglyceride of lauric acid is highly attracted to hair proteins, and due to its low molecular weight and its structure, it is able to penetrate into hair cortex. On the other hand, mineral oil, which is a hydrocarbon, has no affinity towards proteins found in hair and it cannot penetrate through the hair cuticle and reach the cortex, as well as sunflower oil which is mainly linoleic acid triglyceride with a bulky structure and double bonds. However, non-penetrating oils such as mineral oil and sunflower oil may form a film around hair fiber and adsorb to hair cuticle surface helping to avoid hair damage by reducing friction and enhancing hair shine [69, 72, 73]. Among other popular oils used as hair treatments is Morrocan argan oil which is claimed to keep hair moisturized and hydrophobic. Anyhow, there is no enough scientific studies proving beneficial effects of Moroccan argan oil for hair care [74]. Some preliminary studies showed that Buriti oil is very homogeneous in its fatty acid distribution, it has 79% oleic acid causing high specular light reflection and surface gloss [75]. Ucuúba butter showed a slight increase in the stress to break. This butter has a high amount of low molar mass triglycerides composed of short and straight linear fatty acid chains (75% miristic acd (C14)) [75]. Various

oils perform conditioning functions due to their molecular characteristics, such as surface energy, cohesive forces, and surface attaching properties. Most or all of the oils show good performance in reduction of split end formation, and combing resistance. The combing benefit is the result of the decrease in friction on the hair surfaces. The ability of the fatty triglycerides'' attachment to the hair surface and spreading influences the decrease if frictional forces [70].

1.6.2.1 Mineral Oil

Mineral oil is also known as liquid paraffin and it is derived from petroleum. It is a mixture of straight chain hydrocarbons that occur during petroleum distillation process. Paraffin as pure was used for hair care for many years. It is also a well-known ingredient of lotions, creams and other cosmetic products. Using mineral oil in high quantity can clog the pores of the skin leading to insufficient oxygen delivery. It also may cause skin irritation and/or dehydration. However, mineral oil does not penetrate into the epidermis nor into the hair, but it leaves an oily film around the hair surface and by so reducing water loss of hair. Mineral oil is a good hair conditioner and it reduces tangling but using mineral oil too often may cause hair dryness and scalp irritation [76].

1.6.2.2 Coconut Oil

Coconut oil is one of the oils that has been used since the ancient times as a hair care oil and using it has always been associated with a healthy-looking hair suggesting the ability of this oil to prevent cuticle damage due to grooming procedures. In addition to the lubricating effects and film forming abilities, coconut oil was found to be able to penetrate into hair cortex protecting it and providing more strength to hair [77]. Coconut oil is composed of relatively lower fatty acids. It contains mainly lauric acid (C12; 50%) and myristic acid (C14; 20%). It also contains in lower amounts of capric acid (C10; 5%) and palmitic acid (C16; 8.3%), as can be seen in Appendix A2. Coconut oil is extracted from mature and fresh kernel of coconut by mechanical and by natural means with or without the use of head and without going through chemical treatment nor refining procedures. Many different methods are used for the extraction such as cold extraction process, chilling, freezing and thawing method, centrifugation method, fermentation method, aqueous enzymatic extraction method, and hot extraction process [78].

Figure 1-12 Coconut Fruit [79]

1.6.2.3 Linseed Oil

Linseed, also called flaxseed oil, is a colorless or pale-yellow oil which is extracted by cold extraction methods from the seeds of the flax plant. Linseed oil is a great source of omega-3 fatty acid linolenic acid. It is also an excellent source of protein as the protein content varies widely from 10 to 31%, and the main amino acids found in linseed proteins are arginine, aspartic acid, and glutamic acid. The linseed oil we used in our study contains mainly linolenic acid at 50.3%, oleic acid at 22%, linoleic acid at 15.6%, stearic acid and palmitic acid both at around 5.5%. Appendix A3 shows the certificate analysis of the linseed oil used in this study. Linseed oil may be used directly on the hair or it may be incorporated into other haircare products [80].

Figure 1-13 Flaxseed [80]

1.6.2.4 Almond Oil

Almond oil is one of the oils used traditionally for hair care. It smoothes the hair and gives it a softer texture making it easier to comb and protecting it against damage due to grooming habits. Almond oil might be applied directly to hair or it may be incorporated into hair care formulations. There is a variety of extraction methods that can be used to extract

almond oil as solvent extraction method which is widely used for this oil, and as an alternative method the use of pressing is used for almond oil extraction [81, 82]. The almond oil we used in this study has 74.11% oleic acid, 16.70% linoleic acid, 6% palmitic acid and 2.1% stearic acid. The full analysis of the oil can be found in appendix A4.

Figure 1-14 Almond seed [83]

1.6.2.5 Baobab Oil

Baobab tree is widely found in Angola, Zambia, Mozambique, Zimbabwe, and South Africa. The seed oil that is extracted from baobab is used in cosmetic industry and sold internationally. Its high content of linoleic acid and oleic acid is well known to soften the skin and to protect and moisturize the epidermis [84]. The oil also has medical and cosmetic uses. In this study, the oil used was extracted by cold pressing method and had 39% oleic acid, 27.96% linoleic acid and 4.67% stearic acid. The full composition of the oil can be found in appendix A5.

Figure 1-15 Baobab fruit and seeds [85]

1.7 TESTING HAIR PROPERTIES

Hair is a very important constituent of human self-concept and appearance over and above its importance for self-confidence. It is a major characteristic personal element that has a key role in self-perception. However, hair fibers are sensitive to different treatments and external effects even if they are physical, chemical or mechanical. Such effects can cause a major damage and change in hair fiber characteristics and features. There are different techniques and tests in order to evaluate hair physical and chemical damage and changes [40, 67].

1.7.1 Evaluation of Physical and Chemical Properties of Hair

Consumers' perception of a soft, silky hair feeling is associated with the ease of combing of the hair as well as how our hand (skin) glides over the hair fibers. For a smooth wet and dry feel, friction between hair and the skin should be minimized in wet and dry environments. Similarly, for a good feel about bouncing and shaking of the hair while walking and running, friction between hair fibers and bunches of hair fibers should also be low [86]. Tribology is the science and engineering of interacting surfaces in relative motion, including the study and application of the principles of friction, lubrication and wear and is highly interdisciplinary, draws on many academic fields, including physics, chemistry, materials science, biology and engineering. Special care is needed to lay down a protocol for the test methods and the conditions of them in order to guarantee sensitivity and reproducibility of the methods. Not only the test conditions, but also the test substrate, hair tresses, used during the tests may affect the results. Scientists have been aware of the effects of differing hair types on the results of many hair tests, although reasons are still a mystery, therefore where / how the hair tresses are obtained, if they are treated samples, how they were treated, and which chemicals and methods were used to treat them has to be monitored very carefully [87]. The tribology of the hair changes as a function of the various hair care processes and the products used as hair care purposes. There are macro-, micro and nanoscale mechanisms behind these interactions, that make surface roughness, friction, and adhesion very important to hair and skin. Table 1-2 summarizes some of the features and corresponding tribologic attributes of hair. In order to investigate the effects of hair care products, properties of hair are measured before and after the treatment applied to hair. The

tests used for analyzing the physical and chemical changes caused by the treatments or ware and the attributes caused are summarized in Table 1-3 and Table 1-4.

Table 1-2: Desired features and corresponding tribological attributes

Desired hair feature	Tribological attributes
Smooth feel in wet and dry environments	Low friction between hair and skin in respective environment
Shaking and bouncing during daily activities	Low friction between hair fibers and groups of hair
Easy combing and styling	Low friction between hair and comb (plastic) and low adhesion. Note: more complex styles may require higher adhesion between fibers.

Table 1-3: Tests used for analysis of physical properties of hair

Combing (Dry/Wet)
Breaking point/ Tensile strength
Contact angle
Microscopic appearance and diameter measuring (Swelling)
Hydration/ dehydration
Fatigue/ grooming
Lustre
Atomic Force Microscopy
Scanning Electron Microscopy
Differential Scanning Calorimetry
Fluorescence Microscopy
Sensory evaluation tests

Table 1-4: Tests used for analysis of chemical properties of hair

Name of the test	Details	Suggested Method
18-MEA Analysis	To analyze 18-MEA in the upper β layer of the cuticle CMC	LC-MS or GC-FID
Covalently bound fatty acids	Palmitic acid/ Stearic acid/ Oleic acid	TLC/FID or GC-MS
Free fatty acids	Oleic (C18:1)/ Linolenic (C18:3)/ Linoleic (C18:2)/ Hexadecatrienoic acid (16:3)	TLC/FID or GC-MS

Ceramides analysis (Cortical CMC)	Hair ceramide analysis (Non-hydroxy acyl dihydrosphingosine, Non-hydroxy acyl sphingosine, a-hydroxy acyl dihydrosphingosine, a-hydroxy acyl sphingosine, a-hydroxy acyl phytosphingosine)	GC-MS (identification), TLC/FID
Cholesterol sulfate/ Oleate	To analyze cholesterol sulfate and cholesterol oleate in the cortical CMC/hair shaft	LC-MS or GC-FID
Squalene/ Wax esters/ Triglycerides		TLC/FID or HPTLC/Densitometry
Amino acid analysis	Cysteine/Cystine/Serine/Glutamic Acid/ Threonine/ Glycine/Leucine/Valine/Arginine/Aspartic Acid/Alanine/Proline/Isoleucine/Tyrosine/Phenylalanine/ Histidine/Methionine	HPLC or amino acid analyzer

1.7.2 Physical and Mechanical Properties of Hair

Hair is surprisingly strong because of its cortex keratin and its long keratin chains which are compressed to form a regular structure. Hair fibres are extremely flexible as well. The physical proprieties of hair involve resistance to stretching, elasticity and hydrophilic power. Physical proprieties of hair depend mostly on its geometry. Caucasian hair is oval; Asian hair is circular; Afro hair is elliptic, and several mechanical proprieties are directly related with fiber diameters [70]. The diameter of the hair fibers can be measured by a micrometer, or fibers can be sized under the microscope against a micrometer.

1.7.2.1 Tensile Strength

Hair strength is one of the most concerns that people look after. Most people have a strong desire for strong healthy hair, and this is why establishing a method to measure and quantify hair strength became a necessary [70]. Different methodologies have been adopted for this purpose, but it is consequential to consider that the hair complex structure plays an important role in its properties, hence, getting different outcomes out of different methods is not unusual [1]. In general, people determine their hair strength by observing the number of broken hair on a comb or a brush after combing, by observing hair fibers on shower floor, or even by noticing split ends on a mirror. Therefore, it is important to consider if in-vitro hair strength measurement method is intended to simulate, to a certain extent, real life conditions.

The amount of force that is required to break one hair fiber might be the most instinctive indicator of hair strength. It would be expected that this value would drop the more the hair fiber is damaged. This is accurate to a certain extent, but there are many factors that must be considered when evaluating the outcome of this method, taking in hand that the break force of a hair fiber is affected by type of hair, age of hair, temperature of the experiment medium, dimensions of hair fibers [88]. Another important factor to consider is the presence of plasticizers which can noticeably alter the mechanical properties of hair fibers. Water for example is a powerful hair plasticizer that can cause the salt bridges and hydrogen bonds within the hair protein structure to solvate, decreasing the mechanical properties of the hair. Never the less, water content of hair fibers is generally overwhelmingly prescribed by the environment's relative humidity. So, in order to achieve reliable results, all of the previous variables should be monitored and controlled as much as possible. However, it is important to keep in mind that even after taking all the possible precautions, this type of testing will still give results with a relatively high standard deviation, which can be minimized to as much as possible by running a high number of samples [89].

1.7.2.1.1 Resistance to Stretching

In general, the weight needed to produce a natural hair thread rupture is 50-100 g. An average head has about 100,000 to 150,000 hair and all of the hair we carry on our scalp can support 10 to 15 tons. The resistance to breakage is a function of the diameter of the hair thread as well as the condition of its cortex which is negatively affected by chemical treatments, such as bleaching, permeant dying, permanent styling [55, 57, 63]. Water content of the hair is also important because of its plasticizing effect, hair and wool absorb water about 35% of their dry weights [90]. It is well known that the water content of hair is depends on the relative humidity of the environment and the degree of damage of the hair. If the hair is damaged, sites that water will be bound will be increasing because the more hydrophobic di-sulfide bonds will be converting to more hydrophilic cystic acid bods [91]. And also due to the removal of the hydrophobic outermost lepidic layers, penetration of water is encouraged. This is one of the important facts that the researchers should be careful about when setting the experimental conditions of their measurements for characterization of hair. When a certain load is applied on a hair filament, its elongation can be measured and the pattern of stretching and the point of breaking can be observed. However, the cosmetic

chemist needs a quantitative method for the evaluation of hair condition that will yield statistically significant results by using relatively small number of samples. The procedure must also be sensitive enough to minor changes in hair conditions. The results obtained by the methods used should be accurate and reproducible. Selection of the hair types also have an incredible effect on the results and interpretation of the results may not be very easy. The methods used to measure the elasticity and tensile properties of the hair are based on measuring the yield point of a single hair fiber and correlating changes of elasticity and tensile properties of the hair fiber to the certain hair conditions studied during the testing [87, 88]. If a hair fiber is exposed to a progressive stretching (strain) at a given extension rate and the resultant internal forces are measured, "stress-strain" curves are obtained which could be used to characterize the fiber properties [87]. One of the most common tests used to determine the mechanical properties of the hair fiber is "tensile strength test". This test is very often used to monitor the changes caused by the chemical treatments (dying, bleaching, perming or relaxing), or environmental effects, like UV exposure, or effects of grooming on the hair fibers. There are many manually controlled devices used for these tests, but some automated devices are also used because of the tedious nature of the test [87]. One of the most important indication of hair strength involves the amount of force that is required to break an individual fiber and this parameter can be evaluated from the very end of the trace, where the magnitude of the force drops sharply to zero at the break point and this break force is highly dependent on the dimensions of the hair fiber: a thicker fiber will be stronger than a thin one [87]. It is desirable to express "strength" in a manner that is independent of fiber dimensions, so the "break stress" is reported by simply as "force divided by cross-sectional area". Diminishing tensile properties arise as the result of an actual reduction in the number of strength-supporting chemical bonds within the hair fiber, therefore, difference between "the before and after chemical treatment" applied on hair tresses can be monitored by this method. Manual devices are the most common ones where single hair filament is attached into jaws and the force is applied until the fiber is stretched to a point and then breaks. For the automatic measuring devices, the sample preparation involves using a crimping block to precisely mount individual fibers between two brass ferrules and these specimens are then placed in a carousel that attaches to the instrument where the device automatically measures the dimensions of each individual fiber using a laser micrometer and then stretches each fiber

bunch to break, with the subsequent generation of a stress-strain curve [87] (figure 1-12). When increasing strain is applied , the hair behaves like a spring (i.e. its alpha helical protein structure), and when the spring is extended beyond a critical value, it will be distorted and no longer can return to its initial conformation when the strain is removed (this threshold condition is termed the “yield point”) and additional stretching immediately above this condition does not produce any further build-up in the internal force, and at still higher extensions, the fiber ultimately breaks). The break stress for wet hair is around 10% lower than in the dry state due to the plasticizing effect of water [87].

Figure 1-16: Tensile strength testers

1.7.2.1.2 Breaking of Hair Filaments

The presence of broken fibers can be a major problem for some consumers that just seeing broken hair fragments in a brush or comb can be a problem to worry. Broken hair in most cases causes the formation of split ends, but also fibers no longer align as readily, often reducing the perception of hair smoothness, inducing a degree of frizz, lowering shine and hindering a fluid flowing motion [92]. Conventional tensile testing of hair applying a one-time external force or deformation that is sufficient to induce breakage (tensile testing), however, fatiguing involves the repeated application of relatively small stimuli which may be considered better simulation of everyday grooming motion [92]. In a fatigue test, failure is attributed to the gradual propagation of pre-existing flaws within a material, an in these repeated combing tests, hair breakage ultimately results from flaw propagation induced by repeated forces associated with day to day grooming. The distribution of these flaws is statistical in nature, so hair breakage also needs to be treated as a statistical variable. Modelling and characterization of breakage can be performed by fitting a Weibull statistical distribution to the data [92]. By thorough analysis of such test results not only the broken

hair and split ends will be successfully evaluated, but also the effects of chemical treatments (bleaching, dying, perming) as well as the favorable effects of hair care products can be investigated.

1.7.2.2 Wet and Dry Combing

Combing is the individual observation of ease or difficulty when hair is combed. This is directly related to the forces that oppose the action of combing hair and an important attribute in the conditioning of hair and in consumer perception [63]. Early studies to measure the combing resistance of hair was as early as 1970s [93]. Early studies focused on comparing the conditioning effects of the experimental or commercial products, but the relationship between comb-hair/ hair-hair friction and combing force were also studied. First attempts to explain the nature of the combing force curves obtained during the passage of a comb through a hair assembly were made by Tolgyesi and co-workers [94]. There is no standard protocol to conduct combing tests and therefore laboratories developed their slightly different devices, the general principles of all are the same. Assessment of combing forces requires a modified dynamometer or texturometer with one or two non-metallic combs placed on a support [12, 64, 65] (figure 1-13). This method depends on hanging the hair tress over a force measuring instrument, and by using a comb cose to the root end of the tress putting the comb in the correct combing way directly through the tress at a fixed speed and recording the forces that repel the comb's motion starting at the point of insertion and until it gets out of the tip end of the tress [64, 65]. Chemical treatments and daily grooming activities do have noticeable effects on combing forces. Hair straightening alters the resistance to the combing of human hair, and over that, the conditioning agents in hair straightener improve the test results [12].

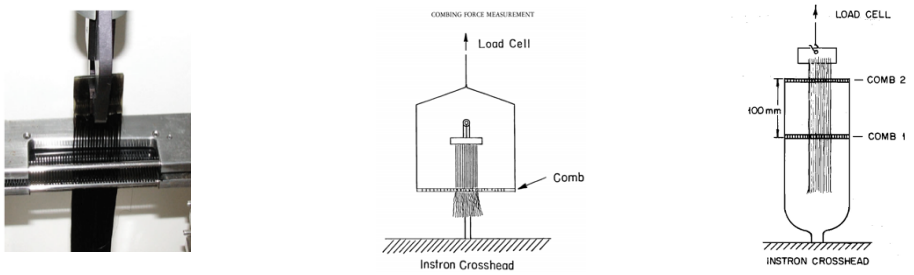


Figure 1-17: Illustration of combing machines [95]

1.7.2.3 Repeated Grooming

Hari breakage resistance is among the top claims regarding shampoos, conditioners and hair care products. Nowadays, anti-breakage products are offered by almost any hair care brands [96]. Sometimes, the appearance of broken hair fibers can be a cause of worry for some people, mainly because broken hair fibers are a sign of hair weakness and split end formation [97]. Hair breakage was tested in literature in different ways, among them is repeated combing of hair tresses, for which, special instruments are used. Usually a repeated combing device constitutes of automated parallel combing of several hair tresses simultaneously where four combs are mounted at 90^{o} angles running at a steady speed allowing four times combing for a tress in a full single round, then the broken hair fibers are collected from separated boxes placed under each drum [92] (figure 1-14). Previous study exhibited a direct relationship between the affinity of hair to break and the magnitude of the applied stress. It concluded how a conditioner with lubricating properties which decreases the stress connected to the repeated grooming will yield a lowered affinity to hair breakage [92].

Figure 1-18: Repeated grooming device

1.7.2.4 Differential Scanning Calorimetry

Hair fibers have rather high thermal stability, therefore drying hair by blowing hot air or temporary styling by using certain devices (hair curling, hair straightening irons) is very common. Some of these devices which are suitable for home use can go up to the temperatures around 230-240 ◦C. Keratin structures like human hair or animal wool have been studied extensively also because of some industrial reasons to characterize these complex structures. Freughelman proposed a two-phase filament-matrix model as early as

1959 that helical fraction of the intermediate filaments, in other words microfibrils, are identified as the crystalline phase, and the matrix and the other structures (cuticula, cell membrane complex and other structures) are the amorphous phase [98]. The glass transition point of hair has been studied by several researchers to understand the behavior of hair to understand the effect of water, chemical treatments, haircare products on hair fibers. DSC is mostly used in order to figure out the glass transition temperature (T_g) of polymers. The heat that is transferred into or out from a specific sample in comparison to a defined reference is measured by DSC [99]. The DSC device has a cell that is constituted of two heating compartments, one of them is for the reference's pan and the other is for the sample's pan, where the reference's pan is usually left empty [100]. The temperature of the sample and the reference most be the same during the whole experiment, and this purpose is achieved and controlled by the device and the software on the computer. The heat capacity of materials such as polymers changes when they undergo chemical or physical changes such as melting, so the device and its software monitor these changes and keep the sample's and reference's temperature the same by applying different heating to each component [100]. For hair, DSC has been used to study the morphological phases and thermal stability of the hair, where denaturation enthalpy is measured and recorded. One previous study concluded that the denaturation enthalpy is a dependent on the strength of the IFs, which are mainly composed of α-helical proteins, and the denaturation temperature depends on the crosslink density of the matrix around the IFs [99]. In most of the experiments, the endothermic process observed was around 230^0 C -235^0 C when DSC of different ethnic hair was investigated [101]. Some chemical changes caused by hair care treatments or products were also assumed to change the peak temperature and endothermic enthalpies, but these were corresponding to the 230^0 C where melting thermal denaturing of alpha–helices and matrix pyrolysis happens. Many of the studies were conducted as regular DSC thermogram analysis, in other words dry, closed (crimped) pans were used to hold the sample. When hair samples were crimped in wet DCS pans, there was another peak which took place less than 150^0 C, and this was related to the changes taking place in cortex; only in the ordered regions showing the disorders in the keratin intermediate filaments also amount of cross-linking in the matrix [102, 103]. These investigations made DSC a method of use to investigate the effects of cosmetic treatments and products.

2 MATERIALS AND METHODS

2.1 MATERIALS AND EQUIPMENTS

2.1.1 Materials

Table 2-1 List of used materials

INCI Name	Trade Name	Supplier
Paraffin Oil	Mineral Oil	Sigma-Aldrich
Cocos Nucifera oil	Coconut oil	Arkem Chemicals
Linum Usitatissimum seed oil	Keten tohumu yağı (Flax seed oil)	Zade Vital AR-Ge ve Üretim Tesisleri
Adansonia digitata oil	Baobab oil	Kupanda African Plant Based Natural Products
Prunus amygdalus dulcis oil	Almond oil	Zade Vital AR-Ge ve Üretim Tesisleri
Bleaching powder	Bleaching powder	Redist
Oxidant cream	L'oreal 40V	L'Oréal Türkiye Kozmetik Tic. ve San. A.Ş.
Sodium Lauryl Sulfate	Texapon N70	BASF Türk Kimya San. ve Tic. Ltd. Şti.
Cocamidopropyl Betaine	Tego Betain F50	Evonik Nutrition & Care GmbH, BL Personal Care
dimethylol-5 5-dimethylhydantoin	Glydant	Lonza Istanbul, Turkiye
Sodium Chloride	NaCl	-
Water (Distilled)	-	-
Nile Red	Nile Red (HPLC Grade)	Sigma Aldrich
Alcohol	Ethanol	
Paraffin wax 56°	Paraplast Bulk	Leica Microsystems

2.1.1.1 Sodium Lauryl Sulfate

Sodium lauryl sulfate is an anionic surfactant used in a wide range of pharmaceutical formulations and cosmetics. It is a detergent and wetting agent that is effective in both alkaline and acidic conditions. It consists of white or cream to pale-yellow colored crystals, flakes, or powder with a smooth feel, a soapy-bitter taste, and a faint odor of fatty substances. It is stable under normal storage conditions but under extreme conditions like when pH goes

down to 2.5 or below, it undergoes hydrolysis to lauryl alcohol and sodium bisulfate. It is prepared by sulfation of lauryl alcohol and then neutralization with sodium carbonate [104].

2.1.1.2 Cocamidopropyl Betaine

Cocamidopropyl betaine is an amphoteric synthetic detergent that has been increasingly used in personal hygiene products and cosmetics. CAPB induces relatively mild skin irritation and contact sensitization prevalence is estimated at between 3.0 and 7.2%. CAPB was named the allergen of the year in 2004 [105].

2.1.1.3 Dimethylol-5 5-dimethylhydantoin

Dimethylol-5 5-dimethylhydantoin (DMDM hydantoin) is an odorless powder or solid that is slightly volatile and is very soluble in water. It is used as antimicrobial agent and preservative in cosmetics. If released to the environment, DMDM hydantoin will break down in air. Direct contact with DMDM hydantoin or its solutions may result in eye damage and skin irritation [106].

2.1.1.4 Sodium Chloride

Sodium chloride is widely used in a variety of parenteral and nonparenteral pharmaceutical formulations, where the primary use is to produce isotonic solutions. Sodium chloride is found as a white crystalline powder or colorless crystals [104].

2.1.1.5 Nile Red

Nile red is an uncharged hydrophobic molecule and a benzophenoxazone dye. It functions as a fluorescent probe for lipids and hydrophobic domains of proteins [107].

2.1.1.6 Bleaching Powder and Oxidant Cream

Other materials as bleaching powder and oxidant cream were purchased locally and used as purchased.

2.1.2 Equipment

Table 2-2 List of used equipment

Equipment	Model	Manufacturer
Analytical balance	E12140	OHAUS
Thermometer	H100	Loyka
pH meter	HI 83141	HANNA Instruments
Light microscope	Leica CME	Leica Microsystems
Liquid paraffin embedding center	Leica EG1160	Leica Microsystems
Microtome	RM2245	Leica Microsystems
Cutting Knives	Patho Cutter-II	ERMA
Microscopic slides	Polusine Slides	Thermo Scientific
Fluorescence microscopy	Axio Vert.A1	Carl Zeiss Microscopy
Fluorescence microscopy software	Zen blue 2012	Carl Zeiss Microscopy
Combing force	--	Custom Made device
Combing force software	--	Custom Made device
Tensile strength	--	Custom Made device
Tensile strength software	--	Custom Made device
Repeated combing (Grooming)	--	Custom Made device
Combs	Hercules No. 366	Hercules Combs
Micropipette	1192T60	United Scientific Supplies
Vortex	MX-S	Toption
Surface tension	KSV CAM100	KSV INSTRUMENTS LTD
Surface tension software	CAM100	KSV INSTRUMENTS LTD
Oven	WOF-155	Wiss. Laboratory Instruments
Syringe filters	Minisart SRP 4	Sartorius
DSC	Hitachi 7000X	Hitachi
Desiccator	262 D/K	Simax

2.2 HAIR SWATCHES / TRESSES

Hair used in this research was dark brown Turkish hair purchased from a local hair dresser. Hair was either used as switches of 3g, 20 cm long and 3.5 cm wide or as individual hair fibers depending on each experiment requirements. Hair switches were used as virgin hair, bleached x1, bleached x4, and bleached x7 samples. Whereas hair fibers were used as virgin hair, bleached x1, bleached x3, bleached x5, and bleached x7 samples.

2.3 PREPARING HAIR FOR EXPERIMENTS

2.3.1 Bleaching Hair

Hair was bleached in accordance with the following steps:

- 70 ml of 40% liquid hydrogen peroxide (LOREAL oxidant crème 3) was added to 40 grams of bleaching powder (REDIST bleaching powder) and was mixed until a smooth creamy consistency is obtained.
- A bleaching brush (REDIST) was used to evenly apply approximately 10 grams of the previously prepared bleaching mix to 5 grams of hair.
- Bleaching mix was rubbed evenly into the hair for 5 minutes.
- Hair was wrapped in foil and left at 25˚C for thirty minutes.
- Hair was then thoroughly washed to remove bleaching mix under a running tap for 5 minutes.
- The previous steps were repeated for repeated bleaching.
- Bleached hair was left to dry overnight at a temperature of 25˚C (±2 ˚C) and a relative humidity of 50% (±5%).

2.3.2 Cleaning Hair

After getting the hair bleached, virgin and bleached hair samples were cleaned using the base shampoo (table 2-3) and tap water with a flow rate of 4 liters/minute and a temperature of 35˚C - 40˚C following the upcoming steps:

- The base shampoo was applied onto the hair swatches by prefilled syringes. The amount of the shampoo was calculated as 0.1g shampoo/1g hair.
- A simple assembly was set up which was made of a hose and a funnel to provide running water at 35-40 ˚C and with a flow rate of 4 liters/minute.
- Hair was wetted out by running it under the tap.
- Excess water was removed by running the first and the middle finger down the length of the hair.
- Hair was laid down on a flat surface and half of the measured shampoo was evenly applied down the length of the hair.

- Shampoo was gently massaged into the hair for 30 seconds.
- Hair was then rinsed for thirty seconds running the first and the middle fingers down the hair every 5 seconds.
- Excess water was removed by tissue.
- The remainder of the shampoo was evenly applied down the length of the hair and massaged for 30 seconds.
- Hair was rinsed with water for 30 seconds running the first and the middle finger down the hair every 10 seconds.
- Excess water was removed.
- Hair was carefully combed, using a wide teeth Hercules comb, from the root to the tip to remove tangling.
- Hair was then left to dry and kept for using at a room temperature of 25˚C ±2 and a relative humidity of 50% ±5.

The base shampoo used in hair cleaning was of the following composition (Table 2-3):

Table 2-3: Composition of base shampoo

Material name	%
Sodium laureth sulfat	12.00
Cocamidopropyl Betaine (Tegobetaine)	1.60
DMDM Hydantoin	0.40
Distilled water	To 100

(pH range of the cleaning shampoo 5.5 – 6.5)

2.4 FLUORESCENCE MICROSCOPY

2.4.1 Preparing Hair Samples for Cross-sectioning

Nile Red was added directly to the oil as following:

2.4.1.1 Preparing oil-Nile Red Solution for dying

A very trace amount of Nile Red (~0.1 mg) was directly added to 10 ml of oil and was mixed with a vortex mixer for 5 minutes. It was then passed through a 0.2 μm syringe filter (Sarorius RC 0.20) to make sure that no solid particles or undissolved Nile Red remains in the oil.

2.4.1.2 Application of oil containing Nile Red on hair

Hair swatches of virgin hair, hair bleached once, and hair repeatedly bleached for 7 times were used. 200-300 hair fibers with a length of 7.5 cm were immersed in 1 ml of oil containing Nile Red for 10 minutes. Hair fibers were then removed out of the oil and gently wiped with a dry tissue and were immediately taken to cross sectioning.

2.4.2 Cross Sections Preparation

For cross-sectioning, treated hair fibers were embedded in melted paraffin (Leica EG1160, Germany) in a parallel alignment. Melted paraffin was then left to solidify for 20 minutes. Solidified block was then mounted onto the microtome (Leica RM2245, Germany). The adjustment of the block was completely perpendicular to the fiber axes. Cross-sections of 5 µm were cut using special stainless-steel blades (ERMA INC. Japan). Three blocks were prepared for each hair sample and sections were mounted onto polysine microscope adhesion slides (Thermo Scientific, Germany) using glycerol.

2.4.3 Fluorescence Microscopy Imaging

For the fluorescence microscopy, cross sections were mounted onto polysine microscope adhesion slides where cross-sections were mounted by using glycerol and were examined under green excitation using an Axio Vert.A1 fluorescence microscope. On average, 20 photos were taken for each sample. A scale bar was used to size the images.

2.5 COMBING FORCE MEASURMENT

Clean and dry hair switches were used in this experiment. Samples of virgin hair, bleached hair x1, bleached hair x4, and bleached hair x7 were treated with 0.1 ml oil per 1g hair. Hair switch was laid down flat on the work surface and half of the measured amount of the oil was applied to each side of the switch. Oil was gently massaged into the hair for 30 seconds using root to tip motion to ensure even spread of the oil over the switch and was then combed once using wide teeth comb to remove severe tangling and help the oil to evenly spread over the switch. Oil was left on the hair for 10 minutes at a temperature of 25˚C (±2 ˚C) and a relative humidity of 50% (±5%) before starting the test. For this experiment, measurements were made on a custom built combing force/ tensile tester device (figure 2-1). Combing was achieved by a Hercules comb with 19 teeth/30 mm which was fixed to the

machine and a smooth retaining bar was used to avoid hair fibers slipping during the measurement. Hair switch was attached to a 20 N load cell and the changes in the load were measured and recorded as the hair was pulled through the comb at a speed of 5 mm/s. The comb was changed each time to avoid samples contamination of the oils. Hair fibers were visually chosen to be of the same thickness.

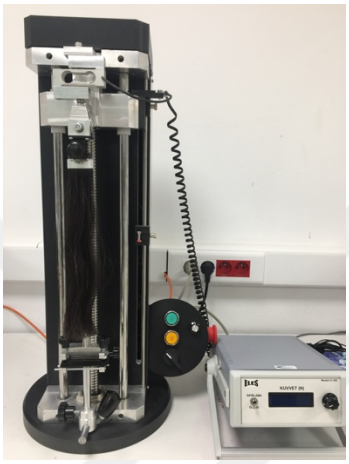


Figure 2-1 Combing force device used in our experiments

2.6 HAIR GROOMING

After measuring the combing forces of the hair, switches were taken to the grooming machine to measure hair breakage due to repeated combing. The experiments were performed on a custom-built device that consists of a hallow rotating drum-like assembly where combing was performed by four combs per strand (swatch) mounted on a motor driven wheel. Combs were mounted to the wheel at an angle of 90˚, allowing the switch to be combed four times during one complete rotation. The machine has four similar horizontally positioned and separated by spacer plats allowing simultaneous combing of four switches at a time. Hair collecting plates are placed under each wheel to save broken fiber fragments (figure 2-2). The combs used in the unit were Hercules combs with 19 teeth /30mm and the experiments were performed at 100 stroke/ minute. All experiments were performed at a temperature of 25˚C ±2 and a relative humidity of 50% ±5. Hair switches were combed in 1000-stroke blocks with consequent counting of the broken fragments in the collecting plates under each switch. Numbers of collected broken fibers were recorded, the collecting plates were cleaned, and the switches were then cycled for another 1000 strokes. This procedure was repeated until a

total of 5000 grooming strokes had been obtained. Data analysis was performed with statistical software SPSS (Build 1.0.0.950 for Mac).

2.6.1 Statistical Analysis

Chi-Square Independence test is used for comparing broken hair ratio for all hair samples after 1000,2000,3000,4000 and 5000 grooming cycles. P values lower than 0.05 were considered statistically significant

Figure 2-2: Repeated grooming device used in our experiments

2.6.2 Hair Weight Measurements

10 sets of 100 clean and dry hair fibers 20 cm long each were weighed at a temperature of 25˚C ±2 and a relative humidity of 50% ±5 using analytical balance (OHAUS Model E12140). In average, it was found that each of the hair tresses used contains approximately 2700 fibers ±130.

2.7 TENSILE STRENGTH MEASUREMENTS

Samples of clean and dry virgin and bleached hair fibers with a length of 10 cm were treated with 0.1 ml oil per 1g hair. Oil was gently rubbed and massaged onto the hair for 30 seconds and was then left for 10 minutes before starting the test. Measurement of the tensile strength was carried out on the custom built combing force/ tensile tester device which was mentioned in section 2.5, with the comb being detached and a hair fiber holder being attached instead so that the hair fiber is held from both sides. The bottom end was fixed still whereas the top end was moving up at a rate of extension of 5 mm/s while attached to the load cell. Each hair filament was introduced to the device one by one and the force at breakage was

recorded for each filament. The test was run for samples of virgin hair, bleached hair x1, bleached hair x3, bleached hair x5, and bleached hair x7, for a sample size of 50 fibers each run, which were visually chosen to be of the same diameter. By measuring the diameter of 300 hair fibers under the microscope, the average area of the hair fibers for virgin and bleached hair switches was calculated. These average hair fiber areas were used to calculate the tensile strength. Tensile properties were measured at a temperature of 25˚C ±2 and a relative humidity of 50% ±5.

2.7.1 Statistical Analysis

Data analysis was performed with statistical software SPSS (Build 1.0.0.950 for Mac). First data was analyzed to determine whether it showed normal distribution (Shapiro Wilks test, $p<0.05$). All analyzed data didn't show normal distribution, therefore nonparametric tests were preferred for statistical analysis. Baseline, mineral oil, coconut oil, linseed oil, almond oil and baobab oil groups' stress at break data were tested between and within. Mann Whitney U Test was used for comparing the means of two independent groups. Kruskal-Wallis test was used for comparing means of three or more independent groups. P values equal to or lower than 0.05 were considered statistically significant.

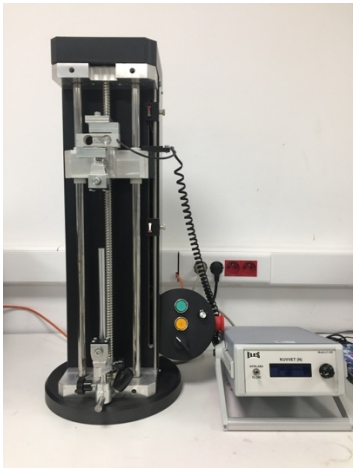


Figure 2-3: Tensile strength testing device used in our experiments

2.8 HAIR POROSITY MEASUREMENT

For this test, petri dishes were washed and dried in the oven at 110 ˚C for 2 hours to constant weight. Dishes were then saved in a desiccator filled with silica gel at a temperature

of 25˚C (±2 ˚C) and a relative humidity of 32% (±0.5%). Clean hair samples (virgin hair, hair bleached x1, hair bleached x4, and hair bleached x7) were wetted with tap water (~35 ˚C). Excess water was removed by carefully tapping the hair with a dry tissue. Oils were then applied to the hair, 0.1 ml oil per 1g hair, and was rubbed onto the hair to achieve even spread over the sample as previously mentioned. Hair was left to dry overnight at a temperature of 25˚C (±2 ˚C) and a relative humidity of 50% (±5%). Weights of the empty petri dishes were recorded and three subsamples of each hair sample each weighing about 100 mg were then put on the petri dishes and instantly moved into the oven. Samples were left in the oven at a temperature of 110 ˚C for 1 hour and were then instantly taken out to the desiccator where they were left for one hour to cool down before weighing again. Temperature and relative humidity inside the desiccator were monitored during the cooling down time and were 25˚C (±3 ˚C) and 35% (±2%) respectively.

2.8.1 Statistical Analysis

Data analysis was performed with statistical software SPSS (Build 1.0.0.950 for Mac). P values equal to or lower than 0.05 were considered statistically significant. Non-treated hair samples, hair samples treated with mineral oil, coconut oil, linseed oil, almond oil and baobab oil water loss data measured by the percentage of weight loss after oven drying were tested between and within. Mann Whitney U Test was used for comparing the means of two independent groups. Kruskal-Wallis test was used for comparing means of three or more independent groups. P values equal to or lower than 0.05 were considered statistically significant.

2.9 DIFFERENTIAL SCANNING CALORIMETRY

Standard DSC thermogram analysis were performed by applying on average 5.0 mg weighed hair sample, which was cut in very fine particles, and put in dry DSC pan and crimping them according to the requirements of the instrument. All initial DCS tests were performed in Yeditepe University Faculty of Chemical Engineering laboratories. All samples were crimped in aluminum DSC pans. Virgin and bleached hair form the baseline for DSC experiments, these tests were aimed to show the effect of bleaching. Then oils were applied to see if they had any effect on the transition peaks or decomposition peaks seen in DSC thermograms. Therefore, thermograms of virgin, bleached once, bleached 4 times and

bleached 7 times hair examples were obtained under nitrogen gas and 10 degrees centigrade/min heating rate. Also, thermograms of virgin hair samples treated with mineral oil (LPV), bleached x1 hair treated with mineral oil (LPB1), virgin hair treated with coconut oil (CCV), bleached x1 hair treated with coconut oil (CCB1), virgin hair treated with linseed oil (LNV) and bleached x1 hair treated with linseed oil (LNB1) were obtained. Due to the unrepeatability of the thermograms, outside sources of DSC facilities were looked for and tests were continued by using a Hitachi a 7000X DSC device in Arel–POTKAM Polimer Teknolojileri ve Uygulama Merkezi, Istanbul. Thermograms of all samples were obtained at a temperature range of 0-270° C at a heating rate of 10°C / min in a nitrogen gas atmosphere. Closed pan, open pan, closed pan with holes and wet closed pan conditions were tried in order to determine the best conditions to test the hair samples. As will be reported in the results, the wet process analysis was found to be the best test condition to use. The samples of LPV, LPB1, CCV, CCB1, LNV and LNV1 were weighed into the pressure pans and 50 µl of distilled water was added, and the pressure pans were crimped tightly, kept for 12 hours before obtaining the DSC thermograms.

3 RESULTS

3.1 FLUORESCENCE MICROSCOPY:

Fluorescence microscopy results are presented by giving two representative pictures of each case and listing the repetitive pictures are given in appendix B. Because of reduced sizes of the pictures in the appendixes, resolution of pictures is reduced, and pictures may not clearly indicate the amount of penetration. By using electronic copy, pictures can be enlarged to see the level of oils penetration for each oil. Table 3-1 summarizes the pictures illustrated for each group of hair samples.

Table 3-1: Summary of the pictures of virgin, bleached once and bleached 7 times under fluorescence microscopy

	Virgin	Bleached 1	Bleached 7
Mineral oil	3-1	3-2	3-3
Coconut oil	3-4	3-5	3-6
Linseed oil	3-7	3-8	3-9
Almond oil	3-10	3-11	3-12
Baobab oil	3-13	3-14	3-15

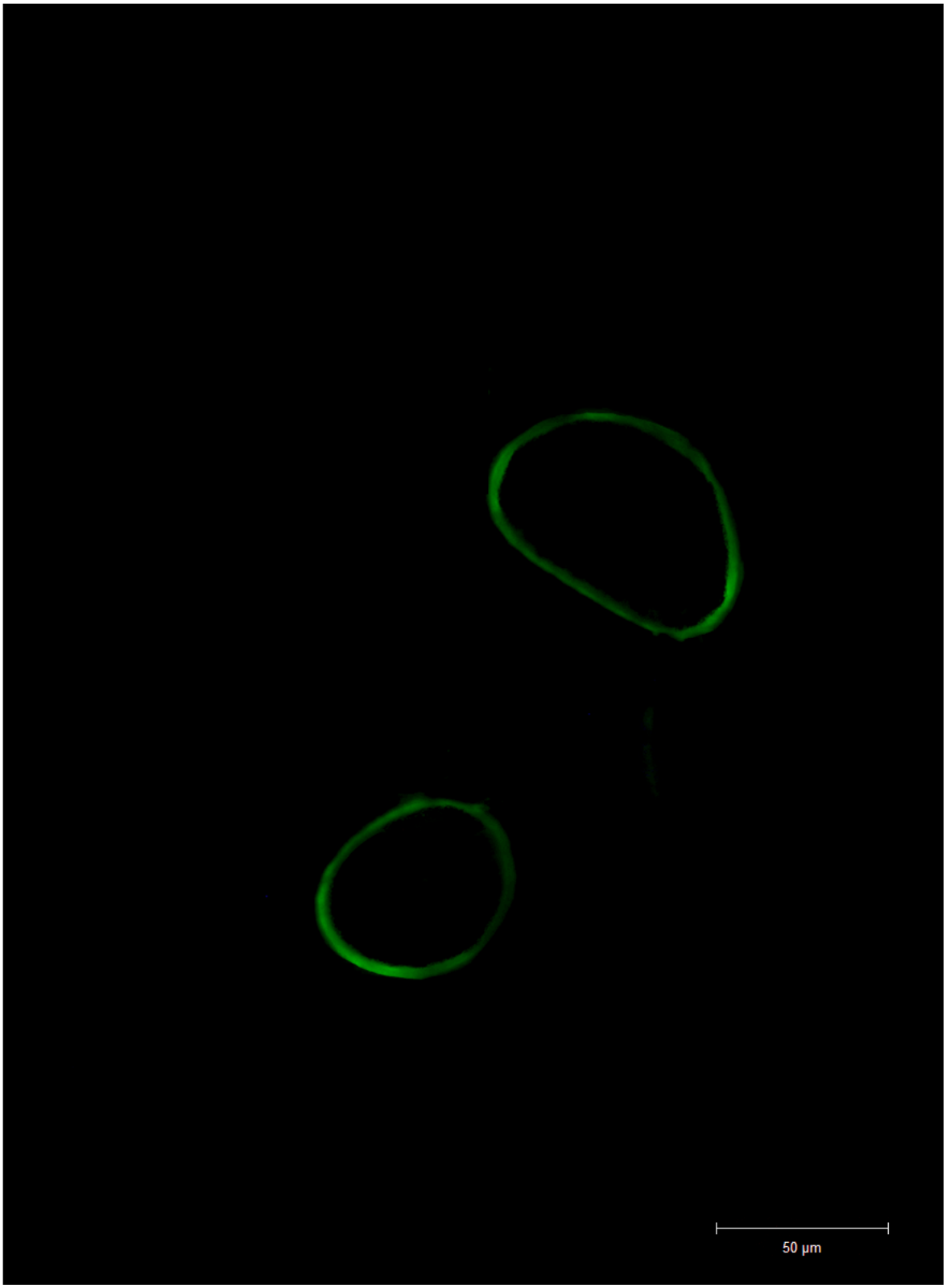


Figure 3-1: Cross-sections of virgin hair treated with mineral oil under fluorescence microscopy

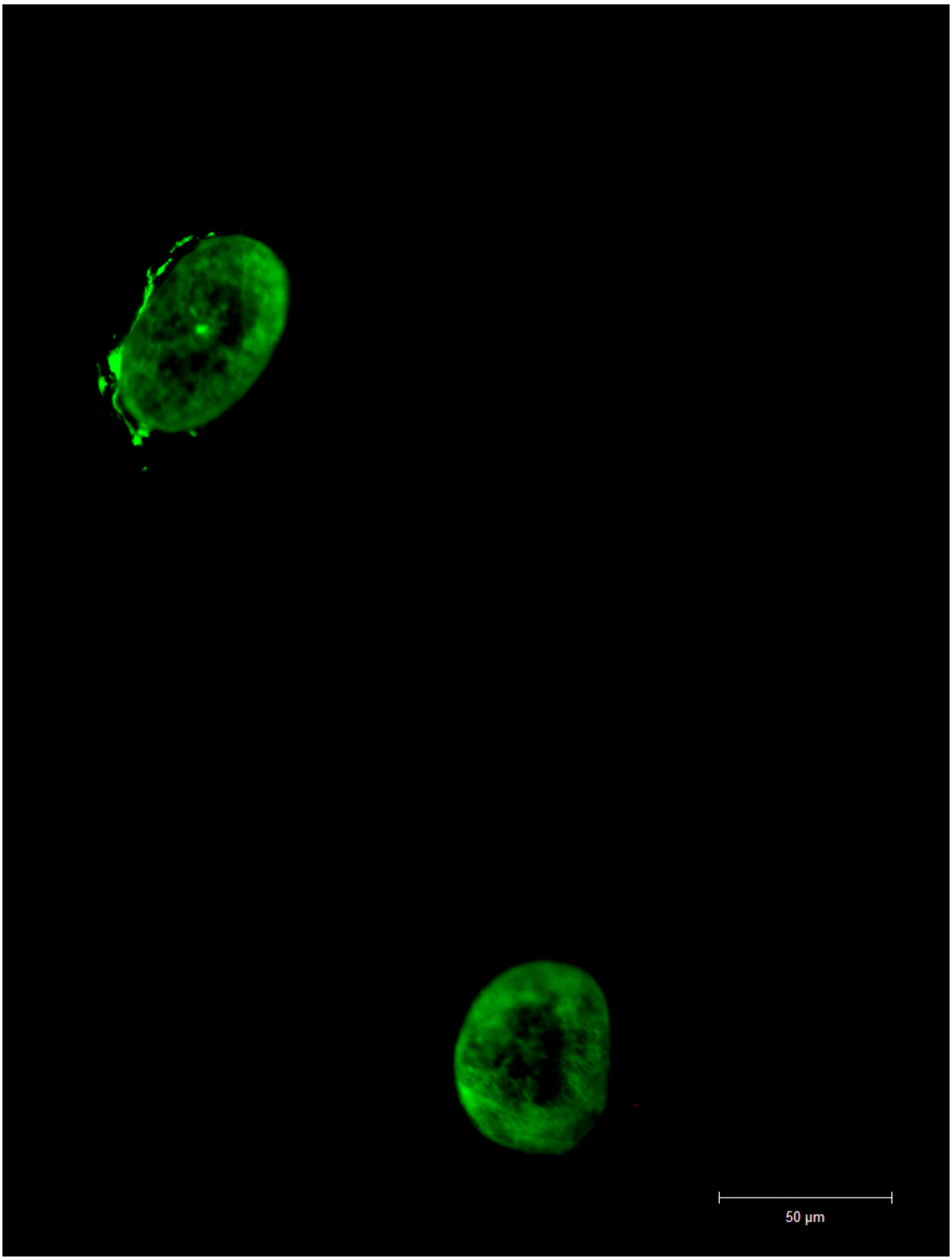


Figure 3-2: Cross-sections of bleached hair x1 treated with mineral oil under fluorescence microscopy

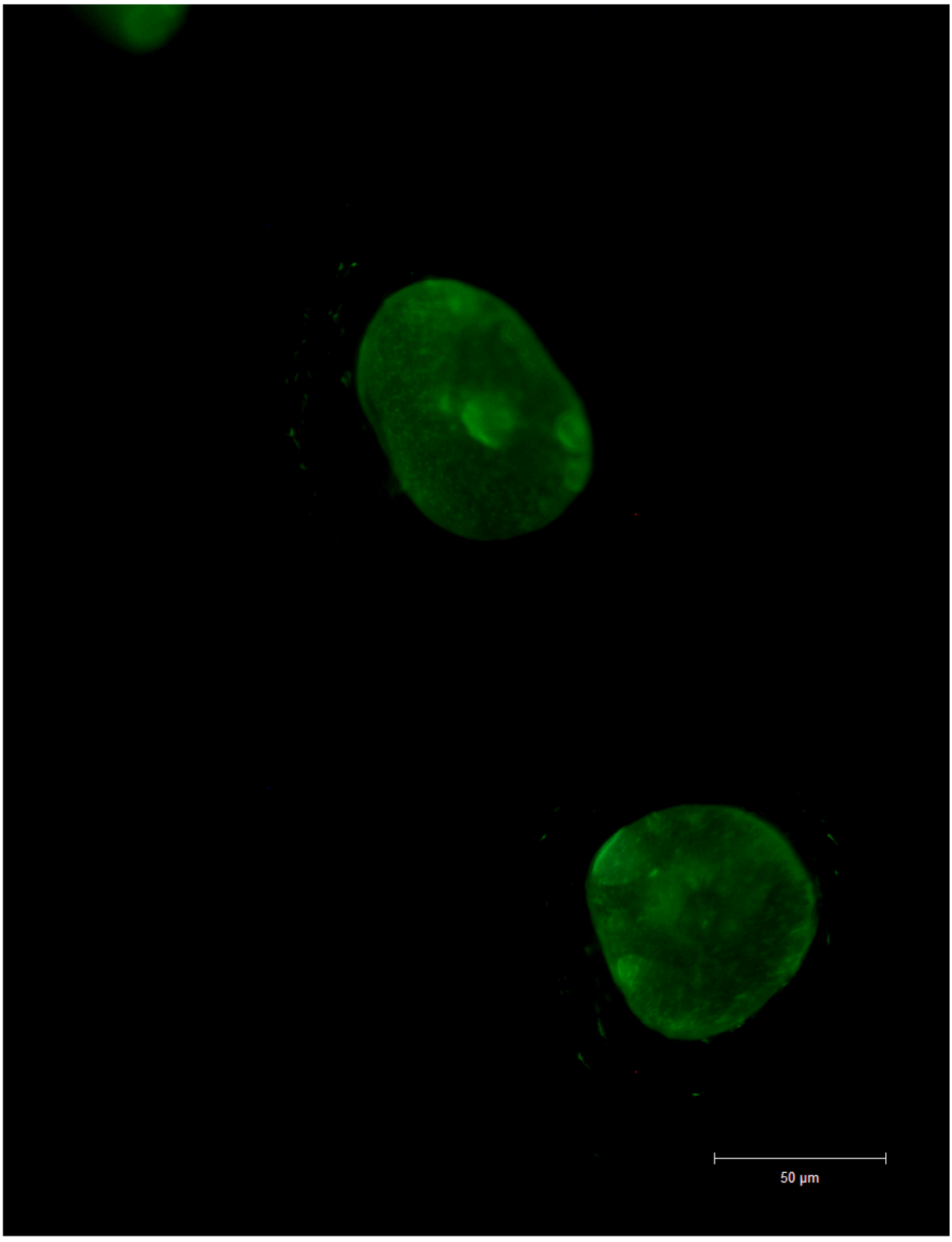


Figure 3-3: Cross-sections of bleached hair x7 treated with mineral oil under fluorescence microscopy

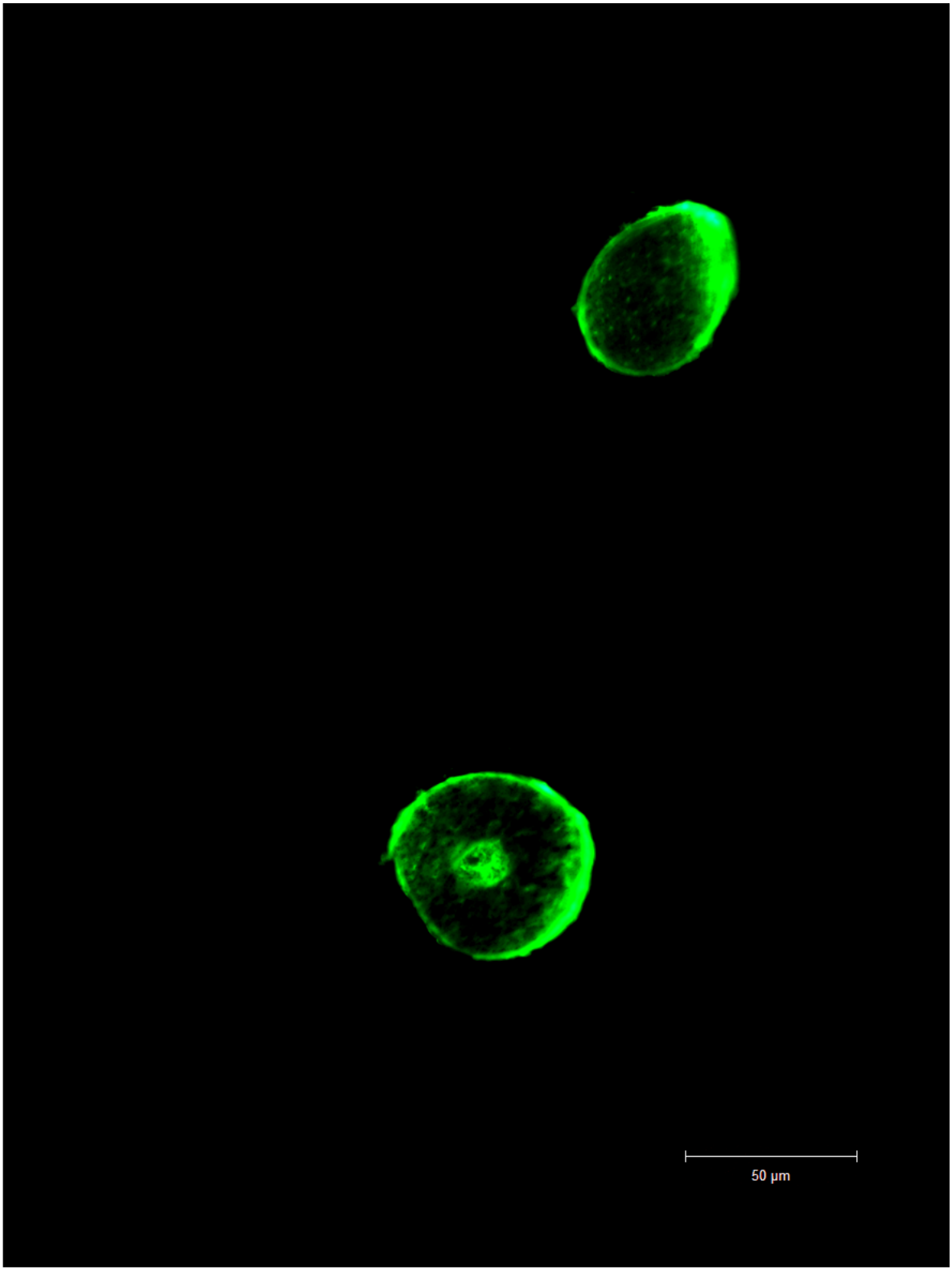


Figure 3-4: Cross-sections of virgin hair treated with coconut oil under fluorescence microscopy

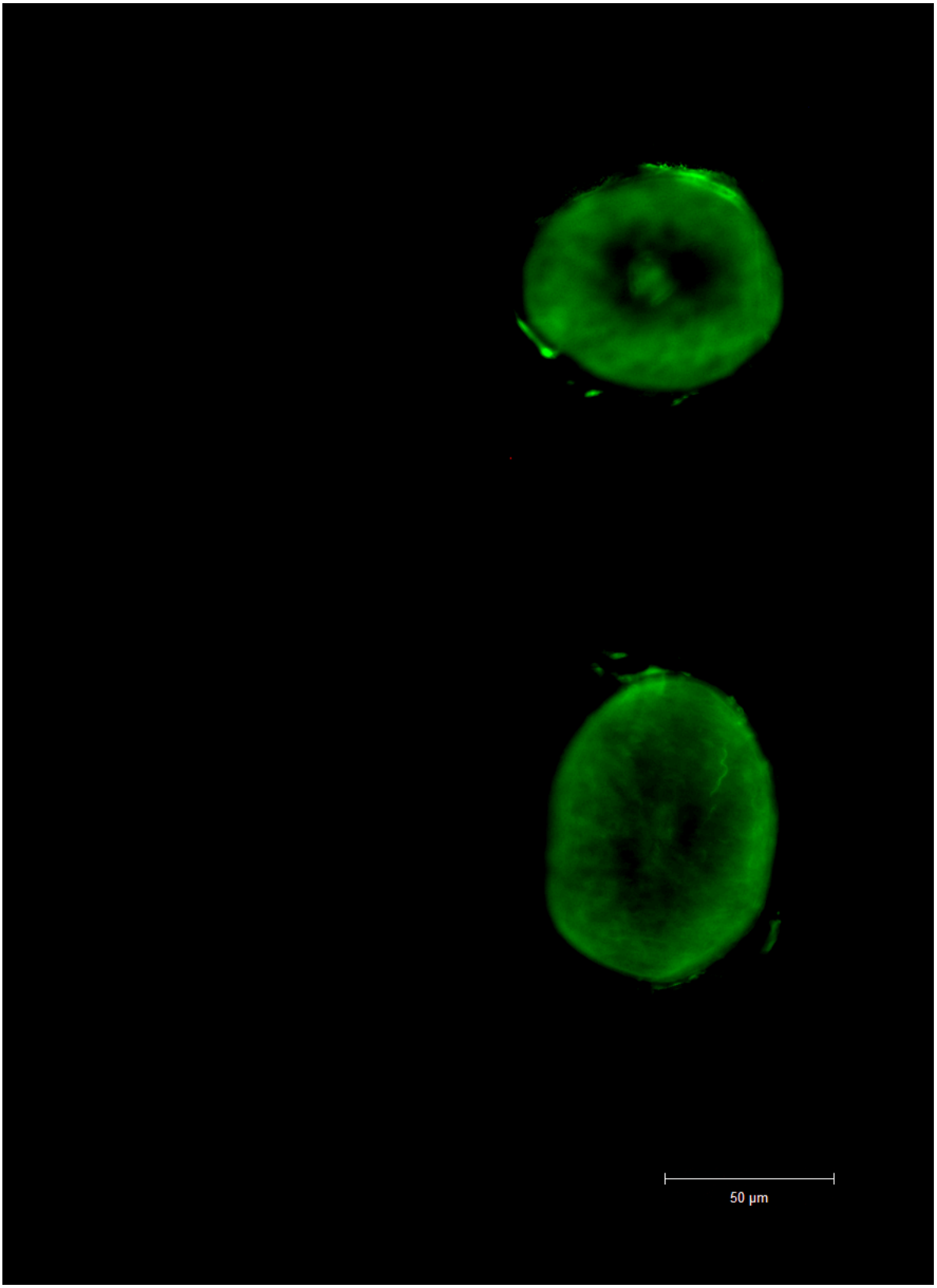


Figure 3-5: Cross-sections of bleached hair x1 treated with coconut oil under fluorescence microscopy

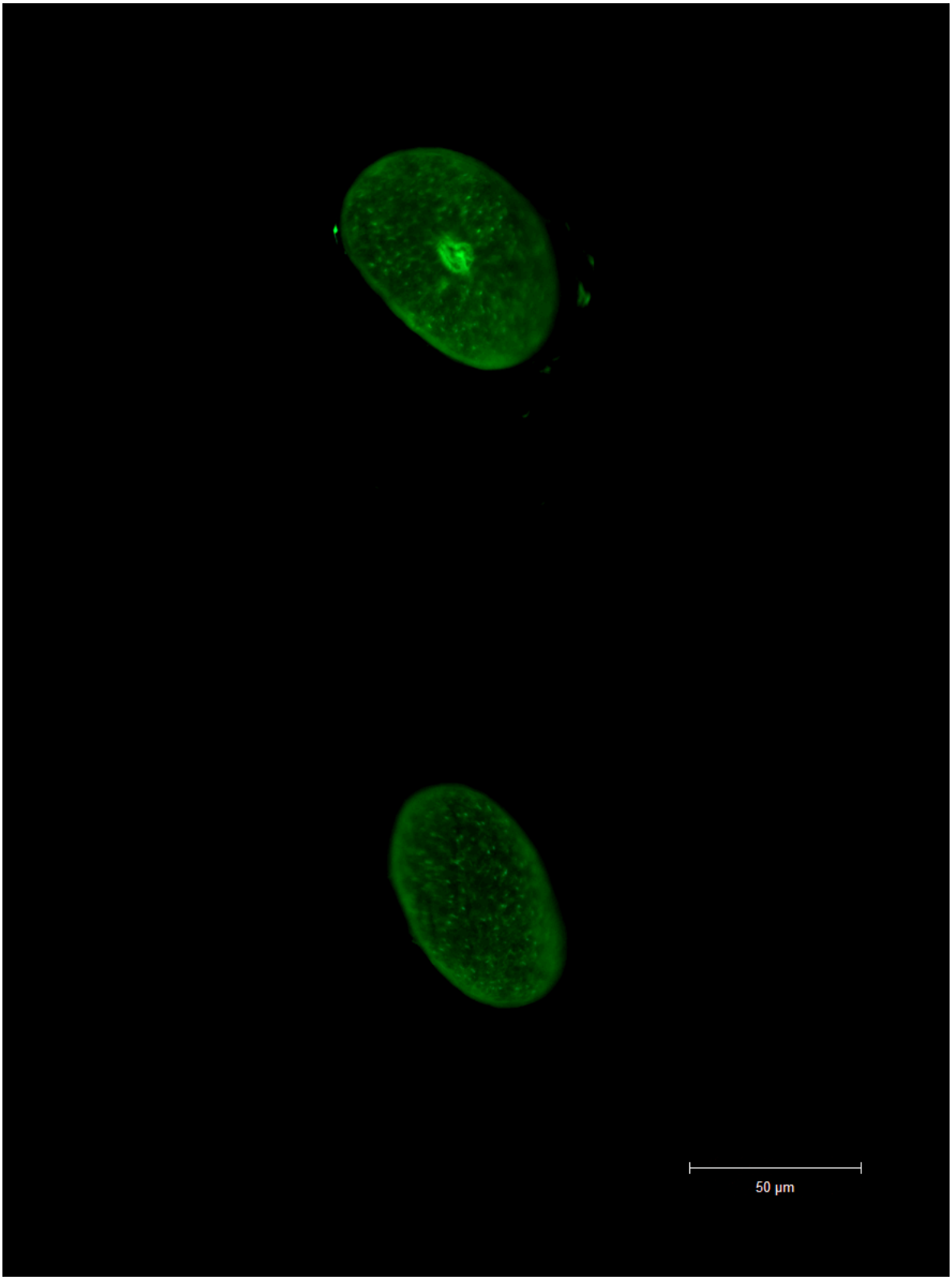


Figure 3-6: Cross-sections of bleached x7 hair treated with coconut oil under fluorescence microscopy

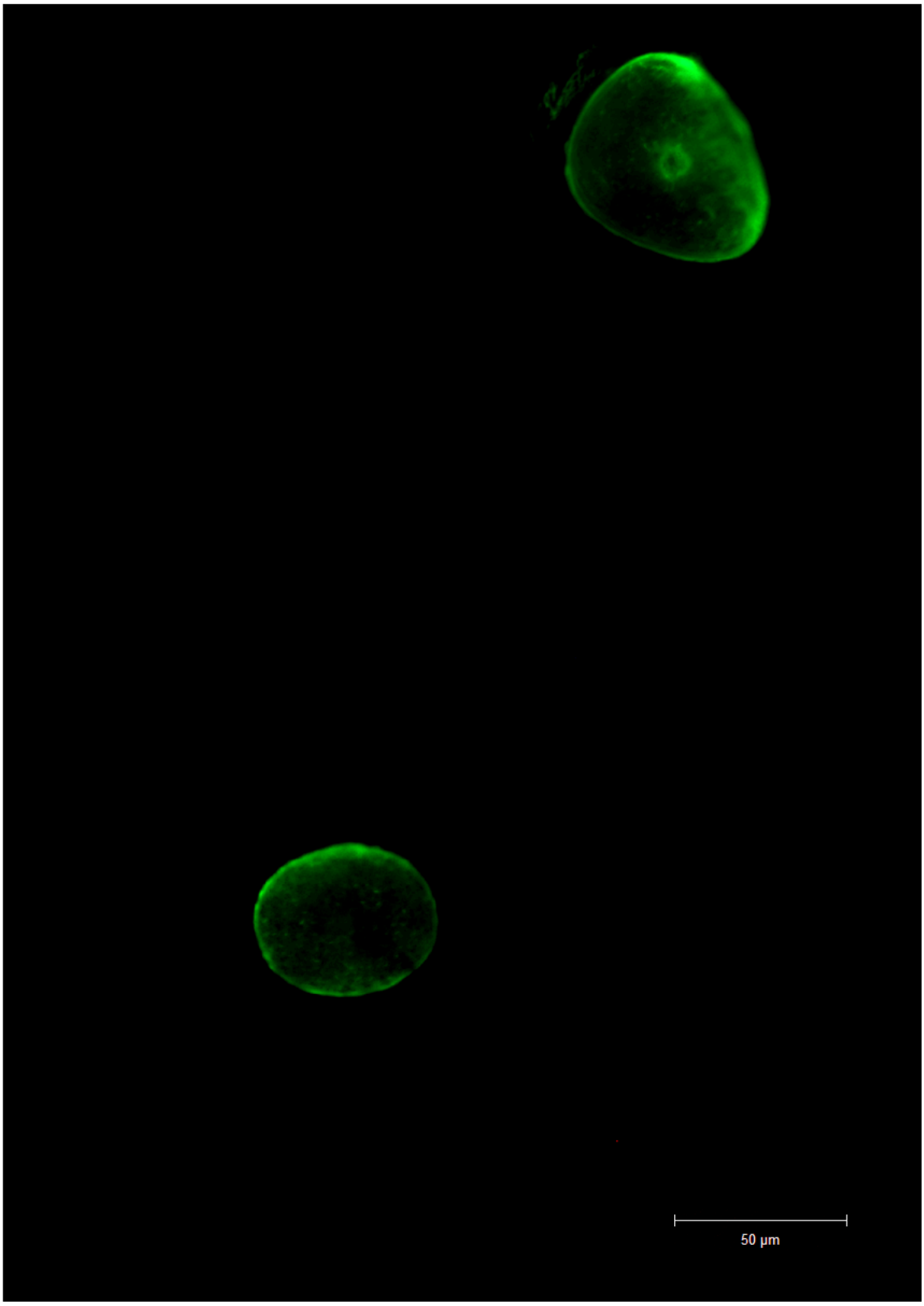


Figure 3-7: Cross-sections of virgin hair treated with linseed oil under fluorescence microscopy

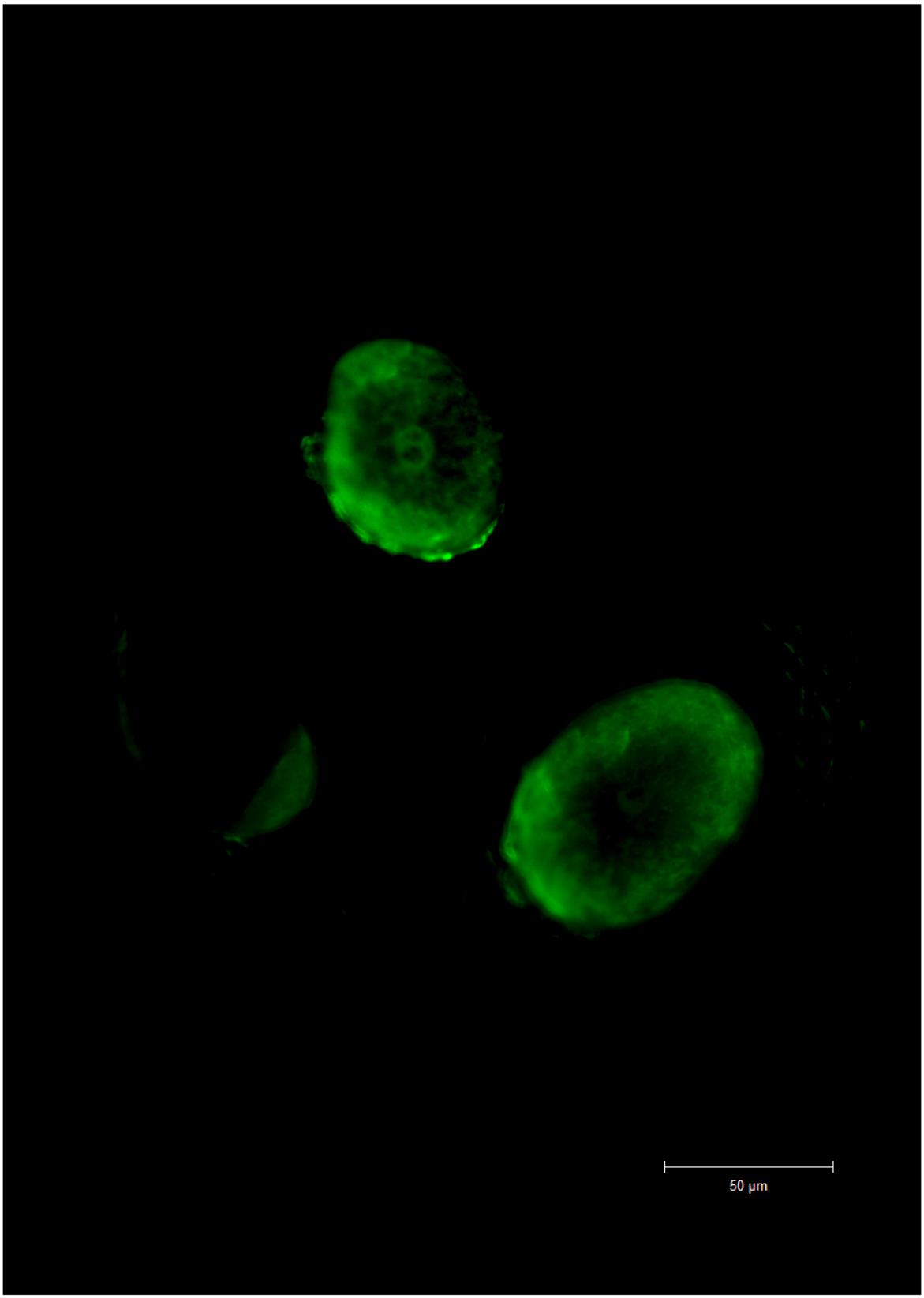


Figure 3-8: Cross-sections of bleached x1 hair treated with linseed oil under fluorescence microscopy

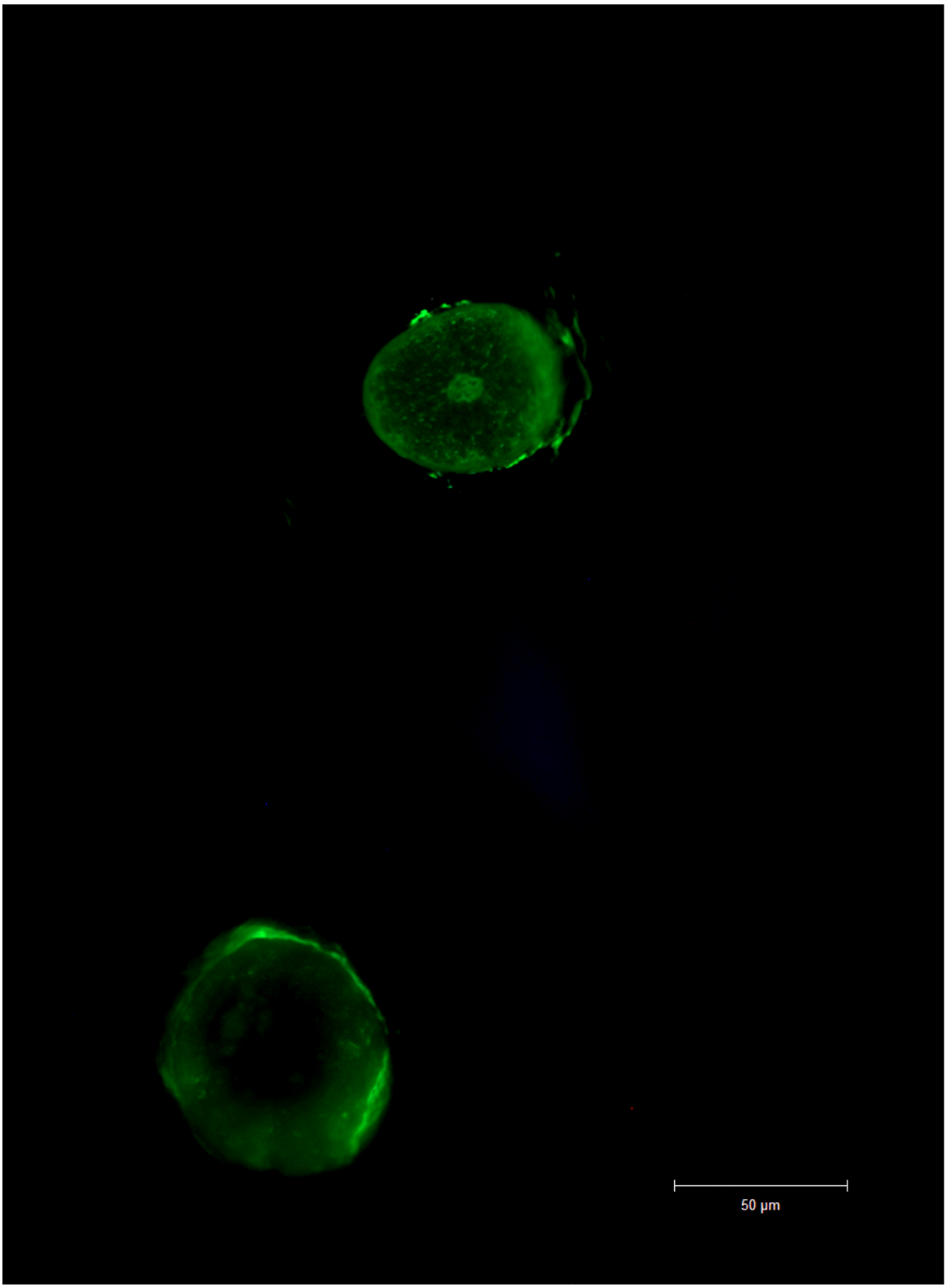


Figure 3-9: Cross-sections of bleached x7 hair treated with linseed oil under fluorescence microscopy

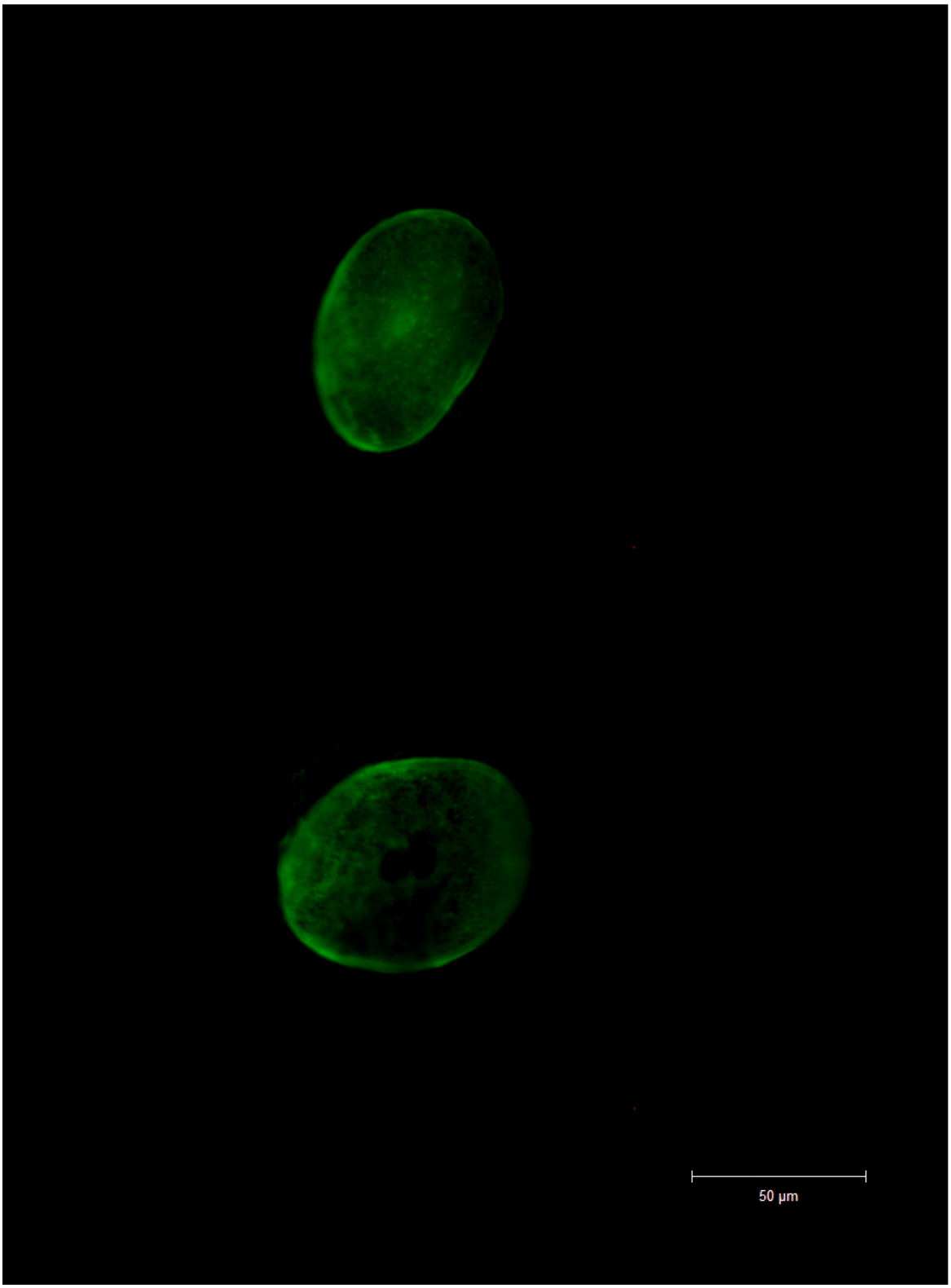


Figure 3-10: Cross-sections of virgin hair treated with almond oil under fluorescence microscopy

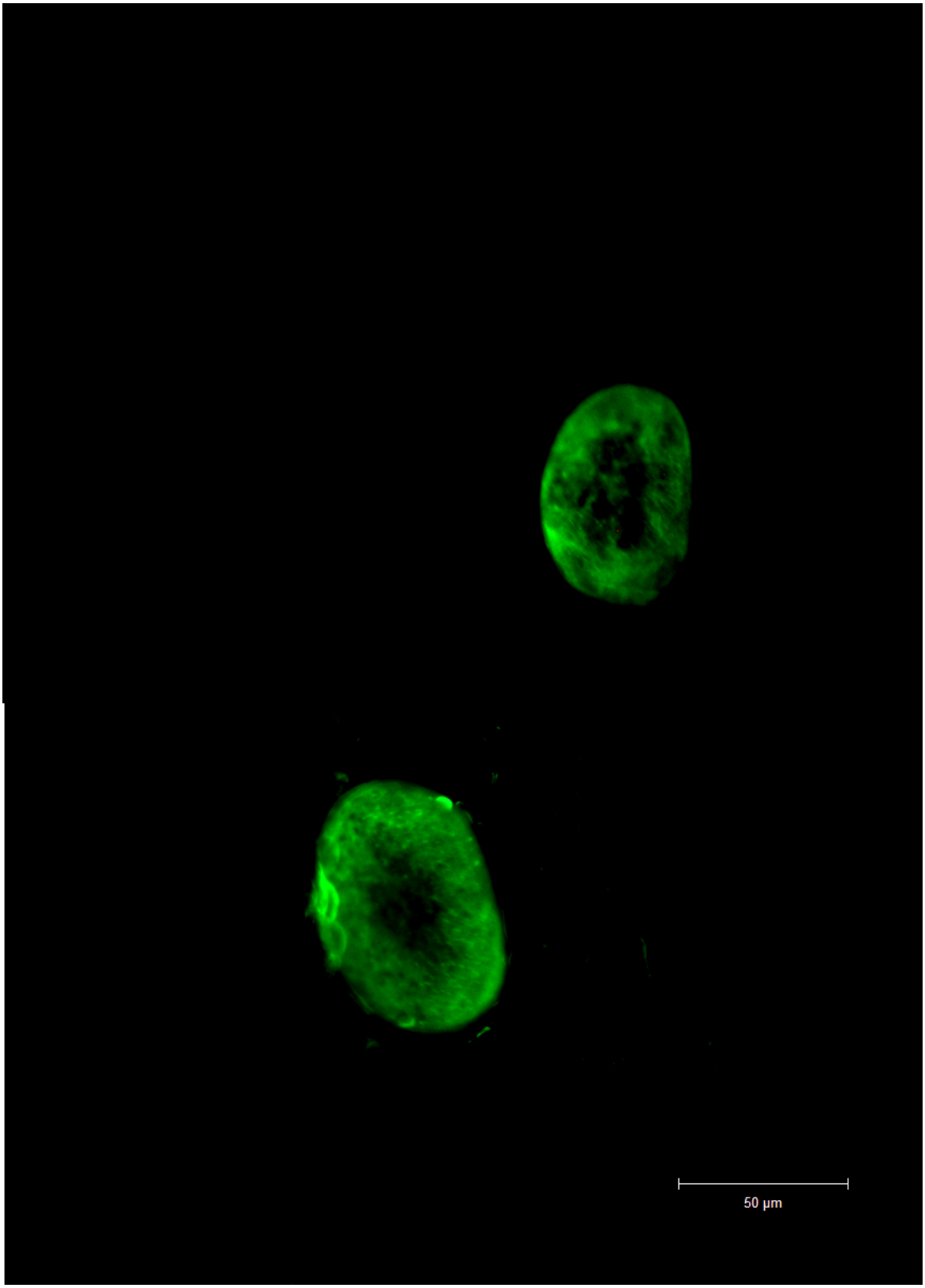


Figure 3-11: Cross-sections of bleached x1 hair treated with almond oil under fluorescence microscopy

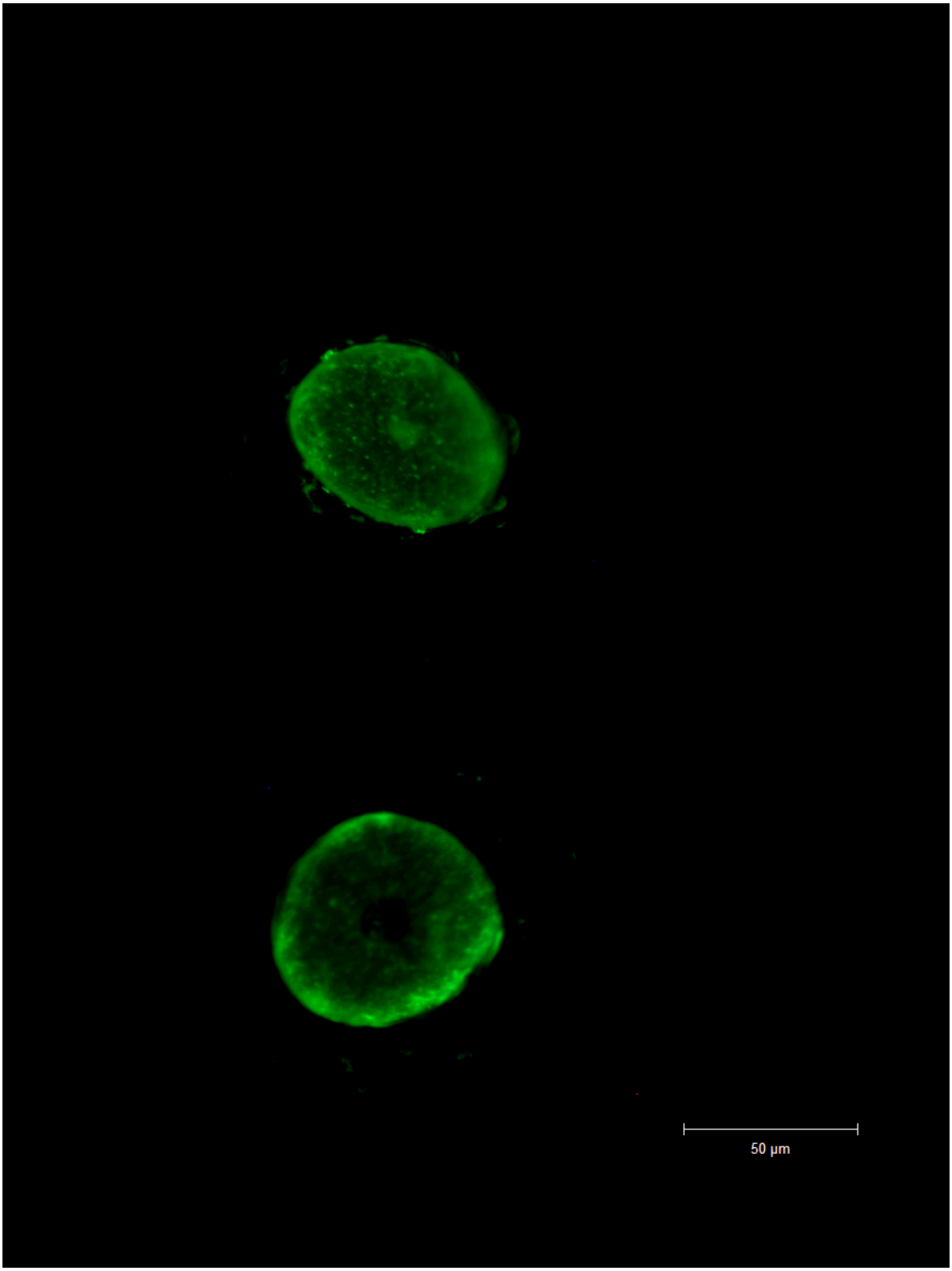


Figure 3-12: Cross-sections of bleached x7 hair treated with almond oil under fluorescence microscopy

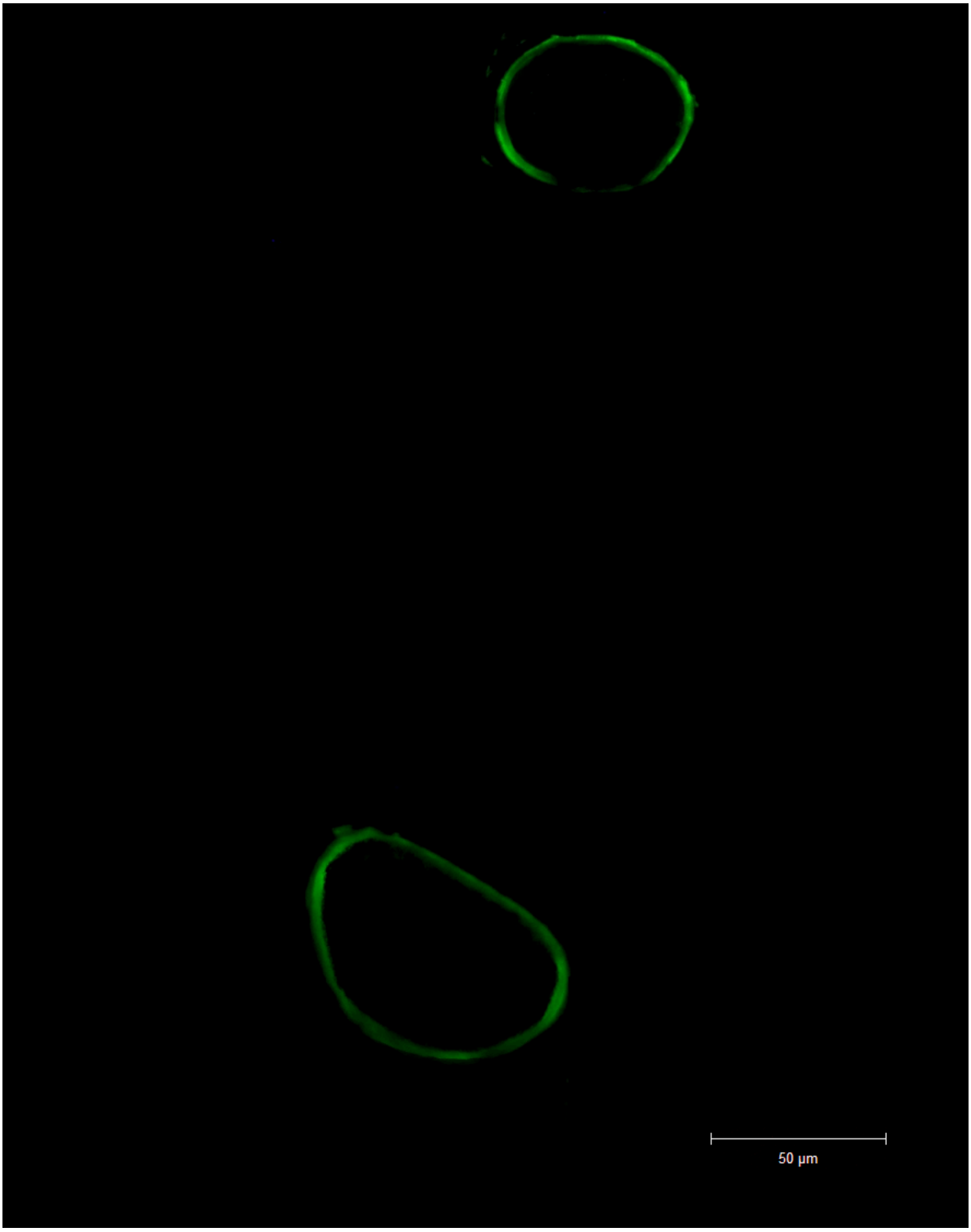


Figure 3-13: Cross-sections of virgin hair treated with baobab oil under fluorescence microscopy

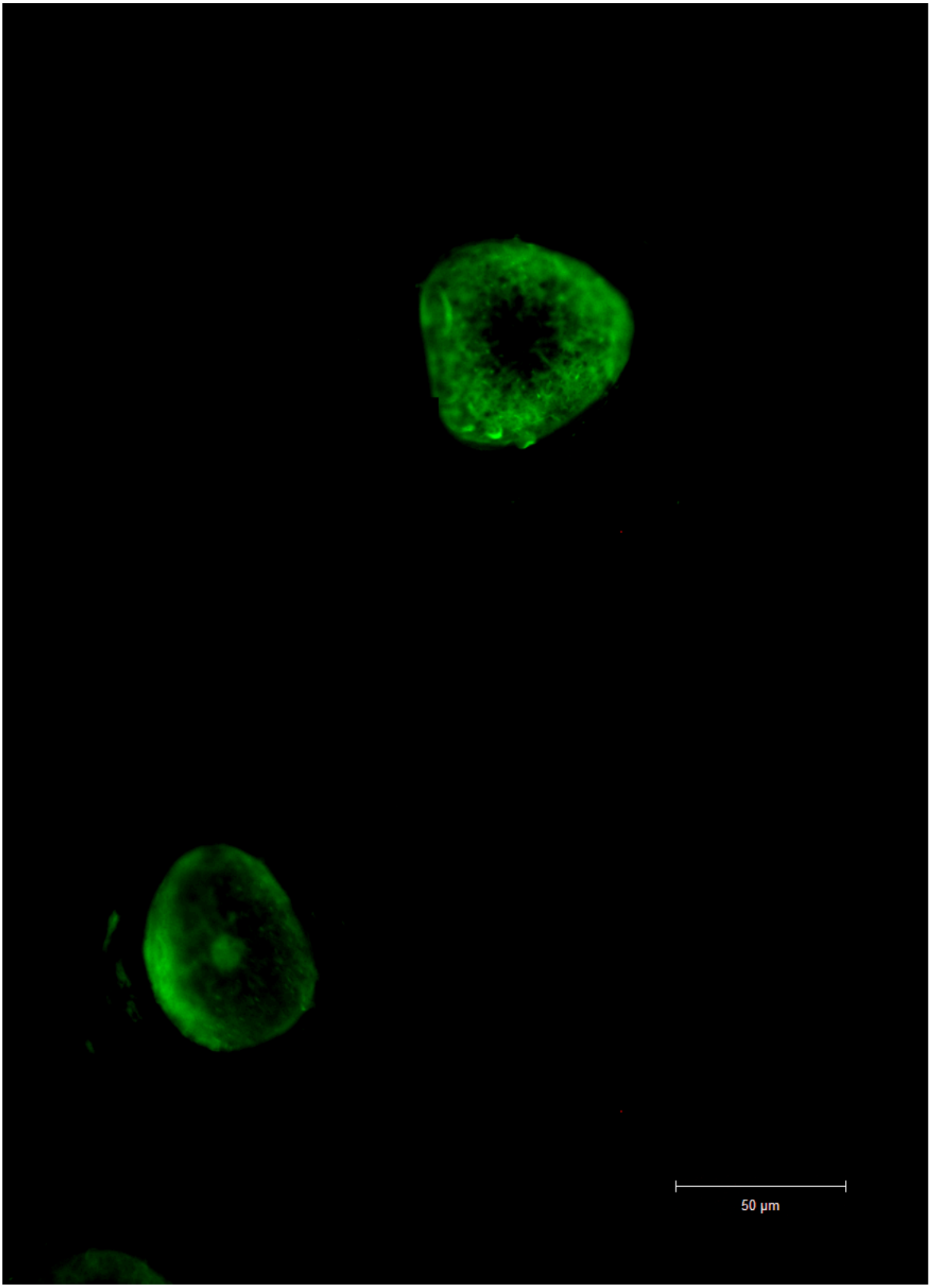


Figure 3-14: Cross-sections of bleached x1 hair treated with baobab oil under fluorescence microscopy

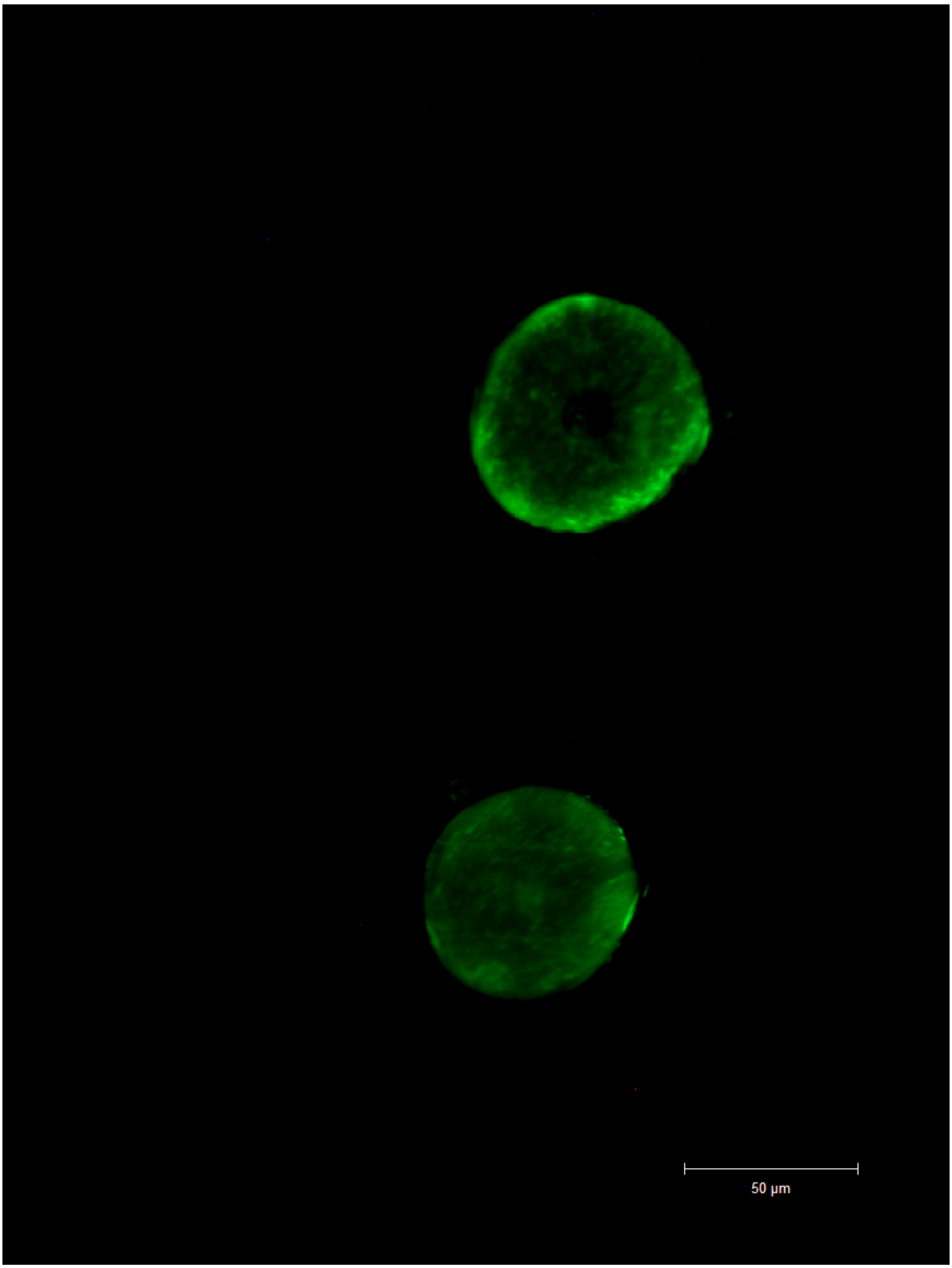


Figure 3-15: Cross-sections of bleached x7 hair treated with baobab oil under fluorescence microscopy

3.2 TENSILE STRENGTH DATA ANALYSIS

Table 3-2: Stress at break data for all hair groups according to oil treatment

	Group	Stress at Break (G-force/cm²) m ± SD	P Value
Baseline	Virgin	522,38 ± 78,86	<.001
	Bleached 1	495,81 ± 73,30	
	Bleached 3	488,60 ± 59,56	
	Bleached 5	444,05 ± 53,67	
	Bleached 7	423,11 ± 65,13	
Mineral Oil	Virgin	502.96 ± 70,67	<.001
	Bleached 1	502.82 ± 73,3	
	Bleached 3	488.02 ± 62,48	
	Bleached 5	441.09 ± 64,29	
	Bleached 7	444.09 ± 48,8	
Coconut Oil	Virgin	546,65 ± 67,06	<.001
	Bleached 1	519,94 ± 64,12	
	Bleached 3	517,08 ± 75,89	
	Bleached 5	472,23 ± 62,53	
	Bleached 7	461,42 ± 60,27	
Linseed Oil	Virgin	614,21 ± 83,36	<.001
	Bleached 1	563,69 ± 96,32	
	Bleached 3	506,62 ± 76	
	Bleached 5	475,12 ± 57,58	
	Bleached 7	467,87 ± 66,36	
Almond Oil	Virgin	539,99 ± 62,69	<.001
	Bleached 1	528,62 ± 69,31	
	Bleached 3	523,71 ± 57,13	
	Bleached 5	506,76 ± 55,08	
	Bleached 7	471,19 ± 66,36	
Baobab Oil	Virgin	529,75 ± 50.02	<.001
	Bleached 1	549,83 ± 56,79	
	Bleached 3	550,82 ± 52,07	
	Bleached 5	497,73 ± 55,27	
	Bleached 7	488,59 ± 56,21	

When compared according to the type of applied oils, mean values of all of the previous samples were different. The differences were statistically different from each other ($P<0.05$).

Table 3-3: Stress at break data for all hair groups according to hair treatment

	Group	Stress at Break (G-force/cm²) m ± SD	P Value
Virgin	Baseline	522,38 ± 78,86	<.001
	Mineral	502.96 ± 70,67	
	Coconut	546,65 ± 67,06	
	Linseed	614,21 ± 83,36	
	Almond	539,99 ± 62,69	
	Baobab	529,75 ± 50.02	
Bleached 1	Baseline	495,81 ± 73,30	<.001
	Mineral	502.82 ± 73,3	
	Coconut	519,94 ± 64,12	
	Linseed	563,69 ± 96,32	
	Almond	528,62 ± 69,31	
	Baobab	549,83 ± 56,79	
Bleached 3	Baseline	488,60 ± 59,56	<.001
	Mineral	488.02 ± 62,48	
	Coconut	517,08 ± 75,89	
	Linseed	506,62 ± 76	
	Almond	523,71 ± 57,13	
	Baobab	550,82 ± 52,07	
Bleached 5	Baseline	444,05 ± 53,67	<.001
	Mineral	441.09 ± 64,29	
	Coconut	472,23 ± 62,53	
	Linseed	475,12 ± 57,58	
	Almond	506,76 ± 55,08	
	Baobab	497,73 ± 55,27	
Bleached 7	Baseline	423,11 ± 65,13	<.001
	Mineral	444.09 ± 48,8	
	Coconut	461,42 ± 60,27	
	Linseed	467,87 ± 66,36	
	Almond	471,19 ± 66,36	
	Baobab	488,59 ± 56,21	

When compared according to the type of hair treatment, mean values of all of the previous samples were different. The differences were statistically different from each other ($P<0.05$).

Table 3-4: Statistical analysis of stress at break data for virgin and bleached x1

	Group	Stress at Break (G-force/cm²) m ± SD	P Value
Baseline	Virgin	522,38 ± 78,86	0.021
	Bleached 1	495,81 ± 73,30	

Means of Baseline Virgin and Baseline Bleached 1 are statistically different from each other (P<0.05).

Table 3-5: Statistical analysis of stress at break data for virgin and bleached x3

	Group	Stress at Break (G-force/cm²) m ± SD	P Value
Baseline	Virgin	522,38 ± 78,86	0.001
	Bleached 3	488,60 ± 59,56	

Means of Baseline Virgin and Baseline Bleached 3 are statistically different from each other (P<0.05).

Table 3-6: Statistical analysis of stress at break data for virgin and bleached x5

	Group	Stress at Break (G-force/cm²) m ± SD	P Value
Baseline	Virgin	522,38 ± 78,86	<.001
	Bleached 5	444,05 ± 53,67	

Means of Baseline Virgin and Baseline Bleached 5 are statistically different from each other (P<0.05).

Table 3-7: Statistical analysis of stress at break data for virgin and bleached x7

	Group	Stress at Break (G-force/cm²) m ± SD	P Value
Baseline	Virgin	522,38 ± 78,86	<.001
	Bleached 7	423,11 ± 65,13	

Means of Baseline Virgin and Baseline Bleached 7 are statistically different from each other (P<0.05).

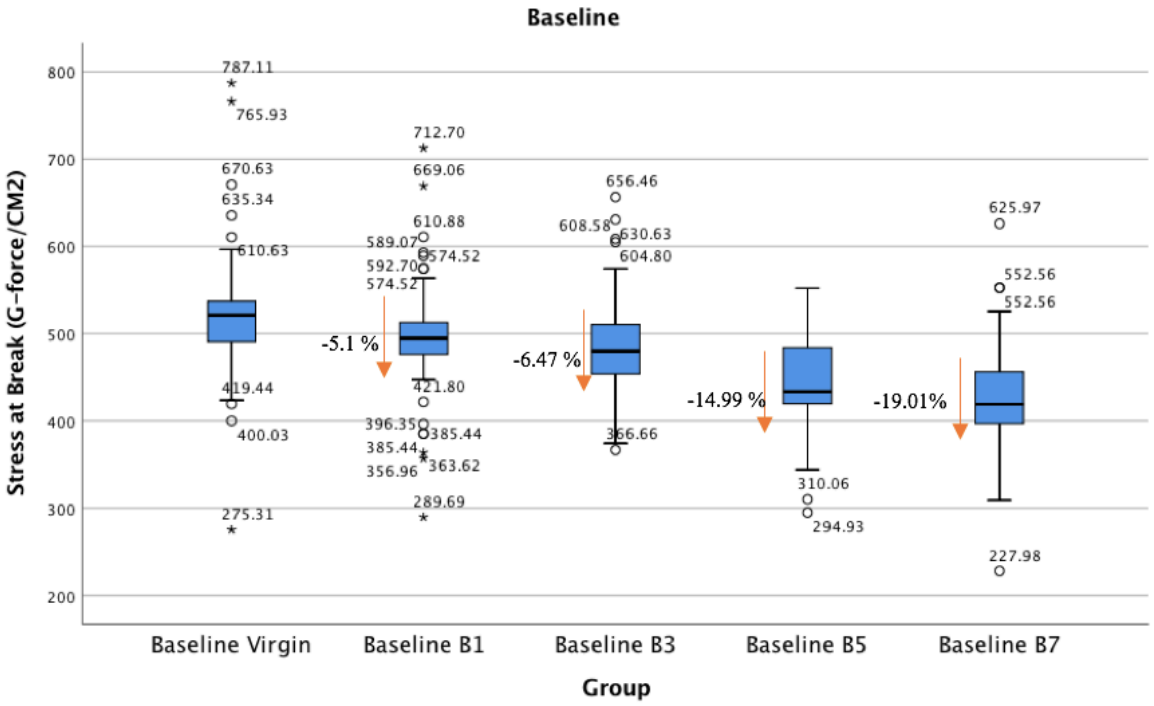


Figure 3-16: Box plot representing stress at break data for baseline non-treated hair samples

Table 3-8: Statistical analysis of stress at break data for virgin and bleached x1 mineral

	Group	Stress at Break (G-force/cm²) m ± SD	P Value
Mineral	Virgin	502.96 ± 70,67	0.863
	Bleached 1	502.82 ± 73,3	

Means of Mineral Virgin and Mineral Bleached 1 are not statistically different from each other (P>0.05).

Table 3-9: Statistical analysis of stress at break data for virgin and bleached x3 mineral

	Group	Stress at Break (G-force/cm²) m ± SD	P Value
Mineral	Virgin	502.96 ± 70,67	0.102
	Bleached 3	488.02 ± 62,48	

Means of Mineral Virgin and Mineral Bleached 3 are not statistically different from each other (P>0.05).

Table 3-10: Statistical analysis of stress at break data for virgin and bleached x5 mineral

	Group	Stress at Break (G-force/cm²) m ± SD	P Value
Mineral	Virgin	502.96 ± 70,67	<.001
	Bleached 5	441.09 ± 64,29	

Means of Mineral Virgin and Mineral Bleached 5 are statistically different from each other (P<0.05).

Table 3-11: Statistical analysis of stress at break data for virgin and bleached x7 mineral

	Group	Stress at Break (G-force/cm²) m ± SD	P Value
Mineral	Virgin	502.96 ± 70,67	<.001
	Bleached 7	444.09 ± 48,8	

Means of Mineral Virgin and Mineral Bleached 7 are statistically different from each other (P<0.05).

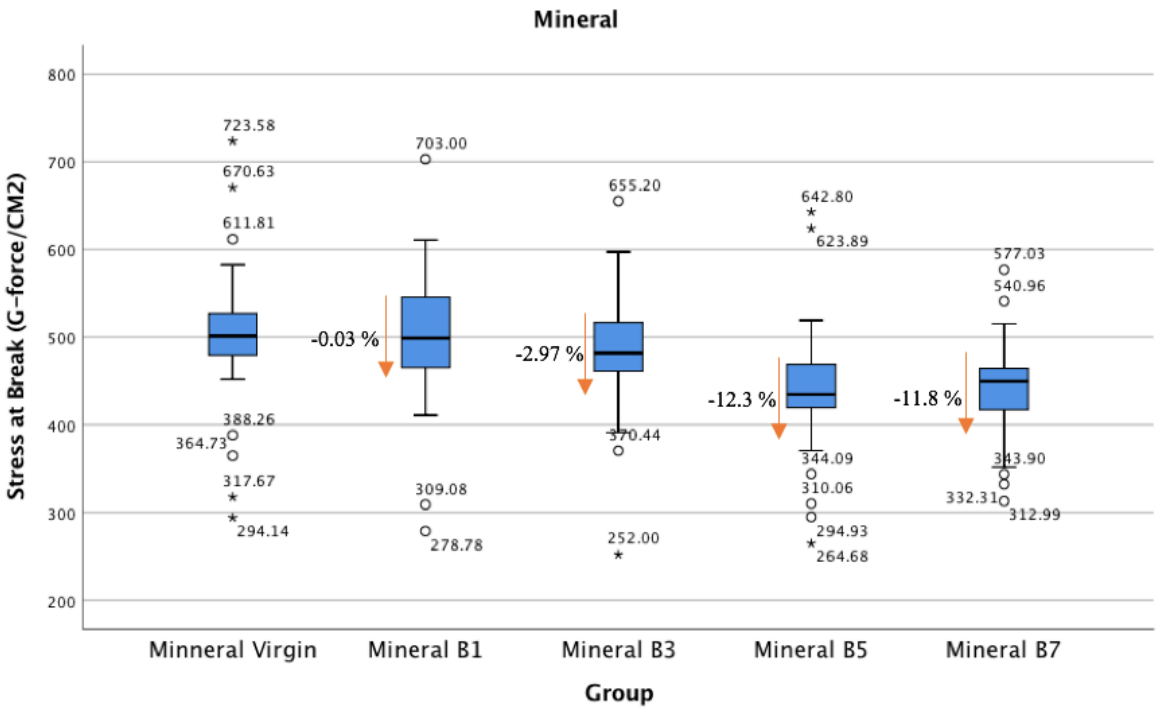


Figure 3-17: Box plot representing stress at break data for baseline mineral oil treated hair samples

Table 3-12: Statistical analysis of stress at break data for virgin and bleached x1 coconut

	Group	Stress at Break (G-force/cm²) m ± SD	P Value
Coconut	Virgin	546,65 ± 67,06	0.007
	Bleached 1	519,94 ± 64,12	

Means of Coconut Virgin and Coconut Bleached 1 are statistically different from each other (P<0.05).

Table 3-13: Statistical analysis of stress at break data for virgin and bleached x3 coconut

	Group	Stress at Break (G-force/cm²) m ± SD	P Value
Coconut	Virgin	546,65 ± 67,06	0.001
	Bleached 3	517,08 ± 75,89	

Means of Coconut Virgin and Coconut Bleached 3 are statistically different from each other (P<0.05).

Table 3-14: Statistical analysis of stress at break data for virgin and bleached x5 coconut

	Group	Stress at Break (G-force/cm²) m ± SD	P Value
Coconut	Virgin	546,65 ± 67,06	<.001
	Bleached 5	472,23 ± 62,53	

Means of Coconut Virgin and Coconut Bleached 5 are statistically different from each other (P<0.05).

Table 3-15: Statistical analysis of stress at break data for virgin and bleached x7 coconut

	Group	Stress at Break (G-force/cm²) m ± SD	P Value
Coconut	Virgin	546,65 ± 67,06	<.001
	Bleached 7	461,42 ± 60,27	

Means of Coconut Virgin and Coconut Bleached 7 are statistically different from each other (P<0.05).

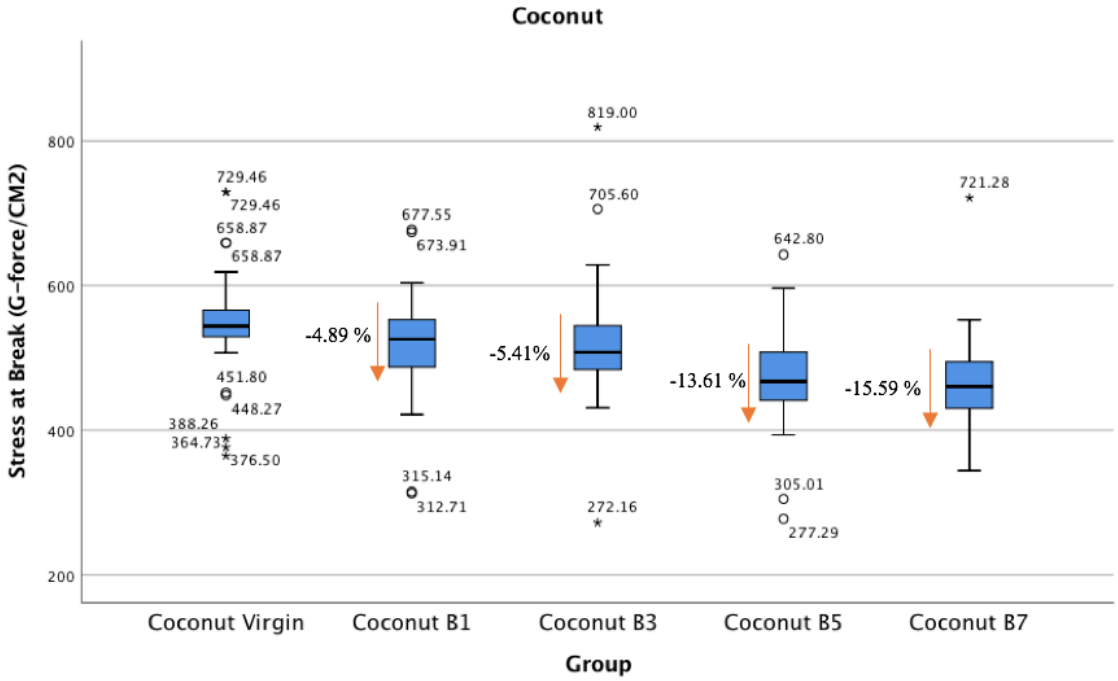


Figure 3-18: Box plot representing stress at break data for baseline coconut oil treated hair samples

Table 3-16: Statistical analysis of stress at break data for virgin and bleached x1 linseed

	Group	Stress at Break (G-force/cm²) m ± SD	P Value
Linseed	Virgin	614,21 ± 83,36	0.001
	Bleached 1	563,69 ± 96,32	

Means of Linseed Virgin and Linseed Bleached 1 are statistically different from each other (P<0.05).

Table 3-17: Statistical analysis of stress at break data for virgin and bleached x3 linseed

	Group	Stress at Break (G-force/cm²) m ± SD	P Value
Linseed	Virgin	614,21 ± 83,36	<.001
	Bleached 3	506,62 ± 76	

Means of Linseed Virgin and Linseed Bleached 3 are statistically different from each other (P<0.05).

Table 3-18: Statistical analysis of stress at break data for virgin and bleached x5 linseed

	Group	Stress at Break (G-force/cm²) m ± SD	P Value
Linseed	Virgin	614,21 ± 83,36	<.001
	Bleached 5	475,12 ± 57,58	

Means of Linseed Virgin and Linseed Bleached 5 are statistically different from each other (P<0.05).

Table 3-19: Statistical analysis of stress at break data for virgin and bleached x7 linseed

	Group	Stress at Break (G-force/cm²) m ± SD	P Value
Linseed	Virgin	614,21 ± 83,36	<.001
	Bleached 7	467,87 ± 66,36	

Means of Linseed Virgin and Linseed Bleached 7 are statistically different from each other (P<0.05).

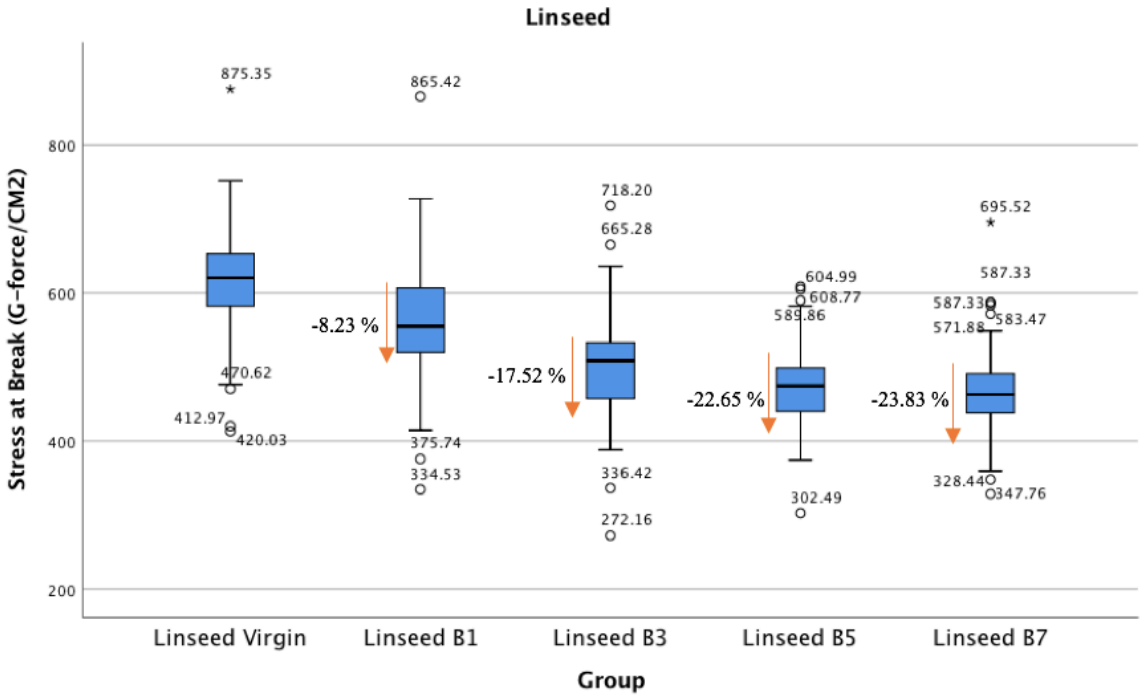


Figure 3-19: Box plot representing stress at break data for baseline linseed oil treated hair samples

Table 3-20: Statistical analysis of stress at break data for virgin and bleached x1 almond

	Group	Stress at Break (G-force/cm²) m ± SD	P Value
Almond	Virgin	539,99 ± 62,69	0,016
	Bleached 1	528,62 ± 69,31	

Means of Almond Virgin and Almond Bleached 1 are statistically different from each other (P<0.05).

Table 3-21: Statistical analysis of stress at break data for virgin and bleached x3 almond

	Group	Stress at Break (G-force/cm²) m ± SD	P Value
Almond	Virgin	539,99 ± 62,69	0.008
	Bleached 3	523,71 ± 57,13	

Means of Almond Virgin and Almond Bleached 3 are statistically different from each other (P<0.05).

Table 3-22: Statistical analysis of stress at break data for virgin and bleached x5 almond

	Group	Stress at Break (G-force/cm²) m ± SD	P Value
Almond	Virgin	539,99 ± 62,69	<.001
	Bleached 5	506,76 ± 55,08	

Means of Almond Virgin and Almond Bleached 5 are statistically different from each other (P<0.05).

Table 3-23: Statistical analysis of stress at break data for virgin and bleached x7 almond

	Group	Stress at Break (G-force/cm²) m ± SD	P Value
Almond	Virgin	539,99 ± 62,69	<.001
	Bleached 7	471,19 ± 66,36	

Means of Almond Virgin and Almond Bleached 7 are statistically different from each other (P<0.05).

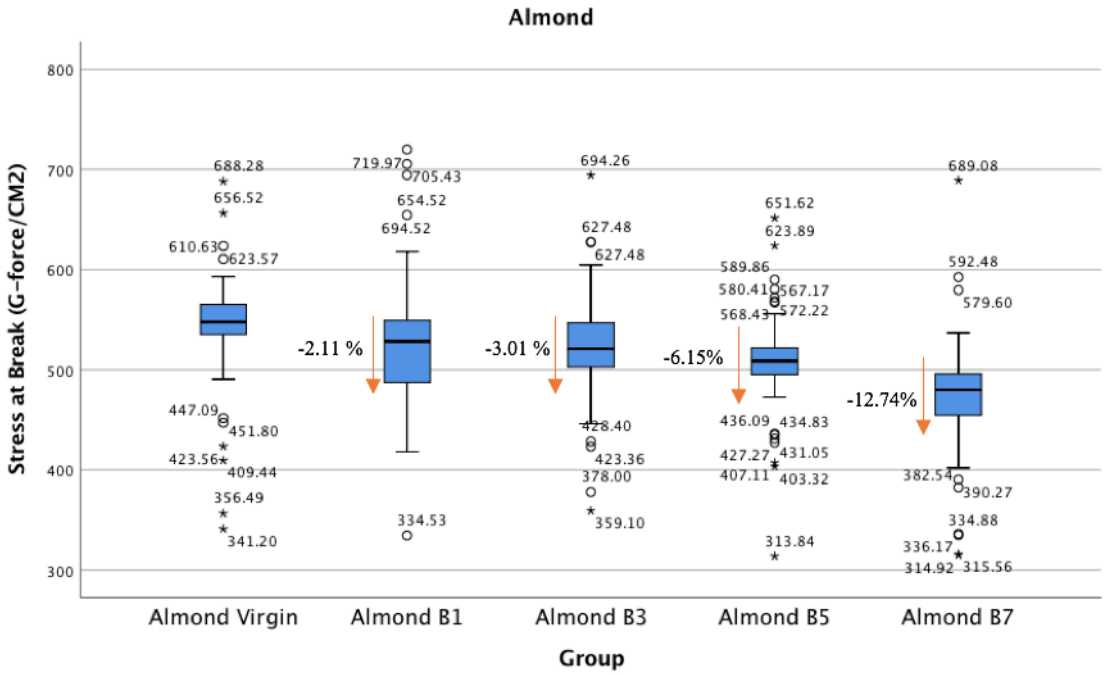


Figure 3-20: Box plot representing stress at break data for baseline almond oil treated hair samples

Table 3-24: Statistical analysis of stress at break data for virgin and bleached x1 baobab

	Group	Stress at Break (G-force/cm²) m ± SD	P Value
Baobab	Virgin	529,75 ± 50.02	0.011
	Bleached 1	549,83 ± 56,79	

Means of Baobab Virgin and Baobab Bleached 1 are statistically different from each other (P<0.05).

Table 3-25: Statistical analysis of stress at break data for virgin and bleached x3 baobab

	Group	Stress at Break (G-force/cm²) m ± SD	P Value
Baobab	Virgin	529,75 ± 50.02	0.024
	Bleached 3	550,82 ± 52,07	

Means of Baobab Virgin and Baobab Bleached 3 are statistically different from each other (P<0.05).

Table 3-26: Statistical analysis of stress at break data for virgin and bleached x5 baobab

	Group	Stress at Break (G-force/cm²) m ± SD	P Value
Baobab	Virgin	529,75 ± 50.02	<.001
	Bleached 5	497,73 ± 55,27	

Means of Baobab Virgin and Baobab Bleached 5 are statistically different from each other (P<0.05).

Table 3-27: Statistical analysis of stress at break data for virgin and bleached x7 baobab

	Group	Stress at Break (G-force/cm²) m ± SD	P Value
Baobab	Virgin	529,75 ± 50.02	<.001
	Bleached 7	488,59 ± 56,21	

Means of Baobab Virgin and Baobab Bleached 7 are statistically different from each other (P<0.05).

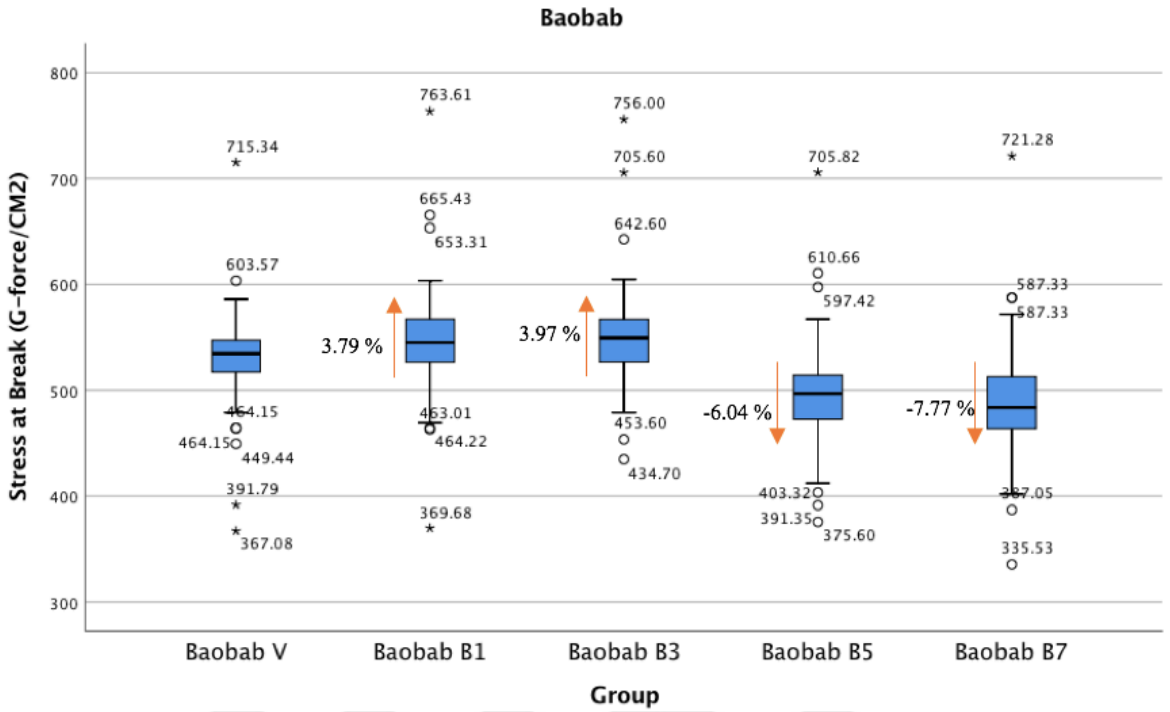


Figure 3-21: Box plot representing stress at break data for baseline baobab oil treated hair samples

Table 3-28: Statistical analysis of stress at break data for virgin hair baseline and mineral oil treated

	Group	Stress at Break (G-force/cm²) m ± SD	P Value
Virgin	Baseline	522,38 ± 78,86	0.070
	Mineral	502.96 ± 70,67	

Means of Virgin Baseline and Virgin Mineral are not statistically different from each other (P>0.05).

Table 3-29: Statistical analysis of stress at break data for virgin hair baseline and coconut oil treated

	Group	Stress at Break (G-force/cm²) m ± SD	P Value
Virgin	Baseline	522,38 ± 78,86	<.001
	Coconut	546,65 ± 67,06	

Means of Virgin Baseline and Virgin Coconut are statistically different from each other (P<0.05).

Table 3-30: Statistical analysis of stress at break data for virgin hair baseline and linseed oil treated

	Group	Stress at Break (G-force/cm²) m ± SD	P Value
Virgin	Baseline	522,38 ± 78,86	<.001
	Linseed	614,21 ± 83,36	

Means of Virgin Baseline and Virgin Linseed are statistically different from each other (P<0.05).

Table 3-31: Statistical analysis of stress at break data for virgin hair baseline and almond oil treated

	Group	Stress at Break (G-force/cm²) m ± SD	P Value
Virgin	Baseline	522,38 ± 78,86	0.001
	Almond	539,99 ± 62,69	

Means of Virgin Baseline and Virgin Almond are statistically different from each other (P<0.05).

Table 3-32: Statistical analysis of stress at break data for virgin hair baseline and baobab oil treated

	Group	Stress at Break (G-force/cm²) m ± SD	P Value
Virgin	Baseline	522,38 ± 78,86	0.045
	Baobab	529,75 ± 50.02	

Means of Virgin Baseline and Virgin Baobab are statistically different from each other (P<0.05).

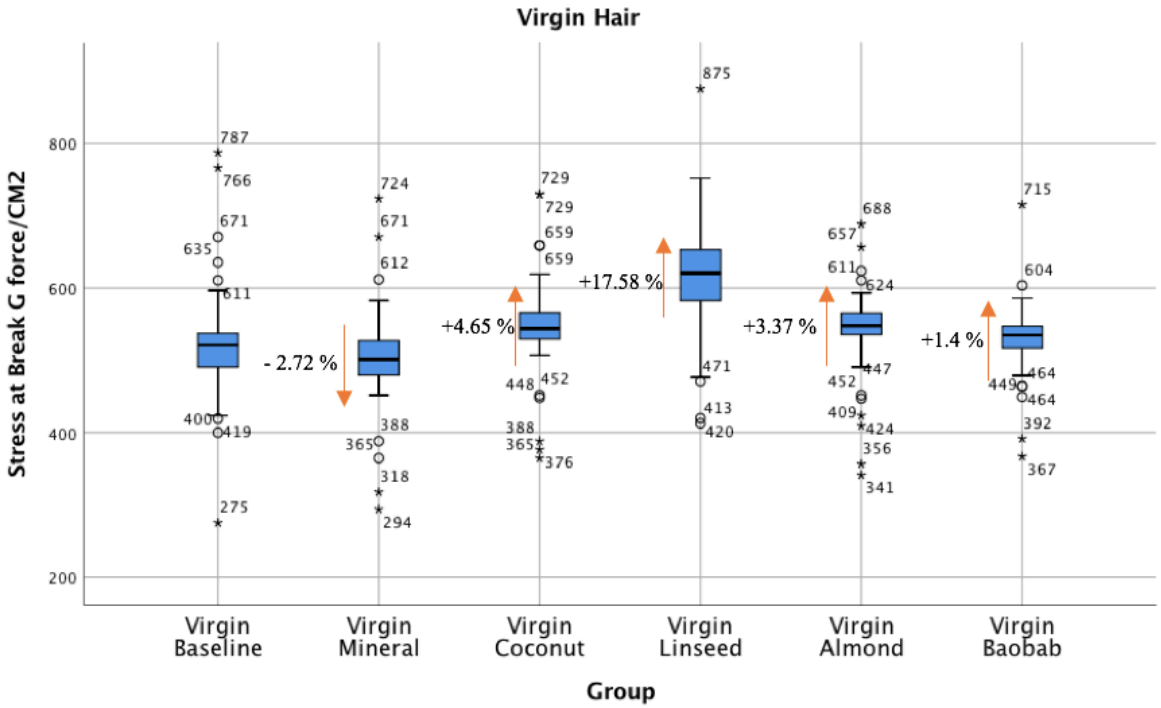


Figure 3-22: Box plot representing stress at break data for virgin hair treated with studied oils

Table 3-33: Statistical analysis of stress at break data for bleached 1 hair baseline and mineral oil treated

	Group	Stress at Break (G-force/cm²) m ± SD	P Value
Bleached 1	Baseline	495,81 ± 73,30	0.542
	Mineral	502.82 ± 73,3	

Means of Bleached x1 Baseline and Bleached x1 Mineral are not statistically different from each other (P>0.05).

Table 3-34: Statistical analysis of stress at break data for bleached 1 hair baseline and coconut oil treated

	Group	Stress at Break (G-force/cm²) m ± SD	P Value
Bleached 1	Baseline	495,81 ± 73,30	0.012
	Coconut	519,94 ± 64,12	

Means of Bleached x1 Baseline and Bleached x1 Coconut are statistically different from each other (P>0.05).

Table 3-35: Statistical analysis of stress at break data for bleached 1 hair baseline and linseed oil treated

	Group	Stress at Break (G-force/cm²) m ± SD	P Value
Bleached 1	Baseline	495,81 ± 73,30	<.001
	Linseed	563,69 ± 96,32	

Means of Bleached x1 Baseline and Bleached x1 Linseed are statistically different from each other (P>0.05).

Table 3-36: Statistical analysis of stress at break data for bleached 1 hair baseline and almond oil treated

	Group	Stress at Break (G-force/cm²) m ± SD	P Value
Bleached 1	Baseline	495,81 ± 73,30	0.010
	Almond	528,62 ± 69,31	

Means of Bleached x1 Baseline and Bleached x1 Almond are statistically different from each other (P>0.05).

Table 3-37: Statistical analysis of stress at break data for bleached 1 hair baseline and baobab oil treated

	Group	Stress at Break (G-force/cm²) m ± SD	P Value
Bleached 1	Baseline	495,81 ± 73,30	<.001
	Baobab	549,83 ± 56,79	

Means of Bleached x1 Baseline and Bleached x1 Baobab are statistically different from each other (P>0.05).

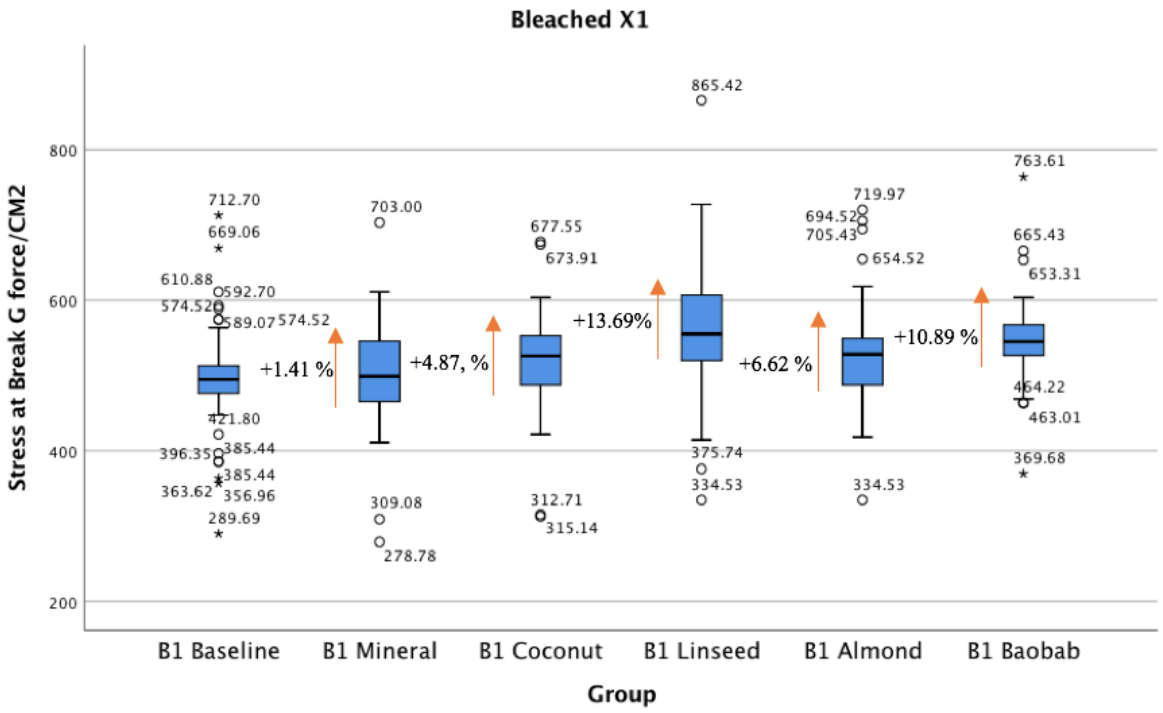


Figure 3-23: Box plot representing stress at break data for bleached x1 hair treated with studied oils

Table 3-38: Statistical analysis of stress at break data for bleached 3 hair baseline and mineral oil treated

	Group	Stress at Break (G-force/cm²) m ± SD	P Value
Bleached 3	Baseline	488,60 ± 59,56	0.610
	Mineral	488.02 ± 62,48	

Means of Bleached x3 Baseline and Bleached x3 Mineral are not statistically different from each other (P>0.05).

Table 3-39: Statistical analysis of stress at break data for bleached 3 hair baseline and coconut oil treated

	Group	Stress at Break (G-force/cm²) m ± SD	P Value
Bleached 3	Baseline	488,60 ± 59,56	0.007
	Coconut	517,08 ± 75,89	

Means of Bleached x3 Baseline and Bleached x3 Coconut are statistically different from each other (P>0.05).

Table 3-40: Statistical analysis of stress at break data for bleached 3 hair baseline and linseed oil treated

	Group	Stress at Break (G-force/cm²) m ± SD	P Value
Bleached 3	Baseline	488,60 ± 59,56	0.044
	Linseed	506,62 ± 76	

Means of Bleached x3 Baseline and Bleached x3 Linseed are statistically different from each other (P>0.05).

Table 3-41: Statistical analysis of stress at break data for bleached 3 hair baseline and almond oil treated

	Group	Stress at Break (G-force/cm²) m ± SD	P Value
Bleached 3	Baseline	488,60 ± 59,56	<.001
	Almond	523,71 ± 57,13	

Means of Bleached x3 Baseline and Bleached x3 Almond are statistically different from each other (P>0.05).

Table 3-42: Statistical analysis of stress at break data for bleached 3 hair baseline and baobab oil treated

	Group	Stress at Break (G-force/cm²) m ± SD	P Value
Bleached 3	Baseline	488,60 ± 59,56	<.001
	Baobab	550,82 ± 52,07	

Means of Bleached x3 Baseline and Bleached x3 Baobab are statistically different from each other (P>0.05).

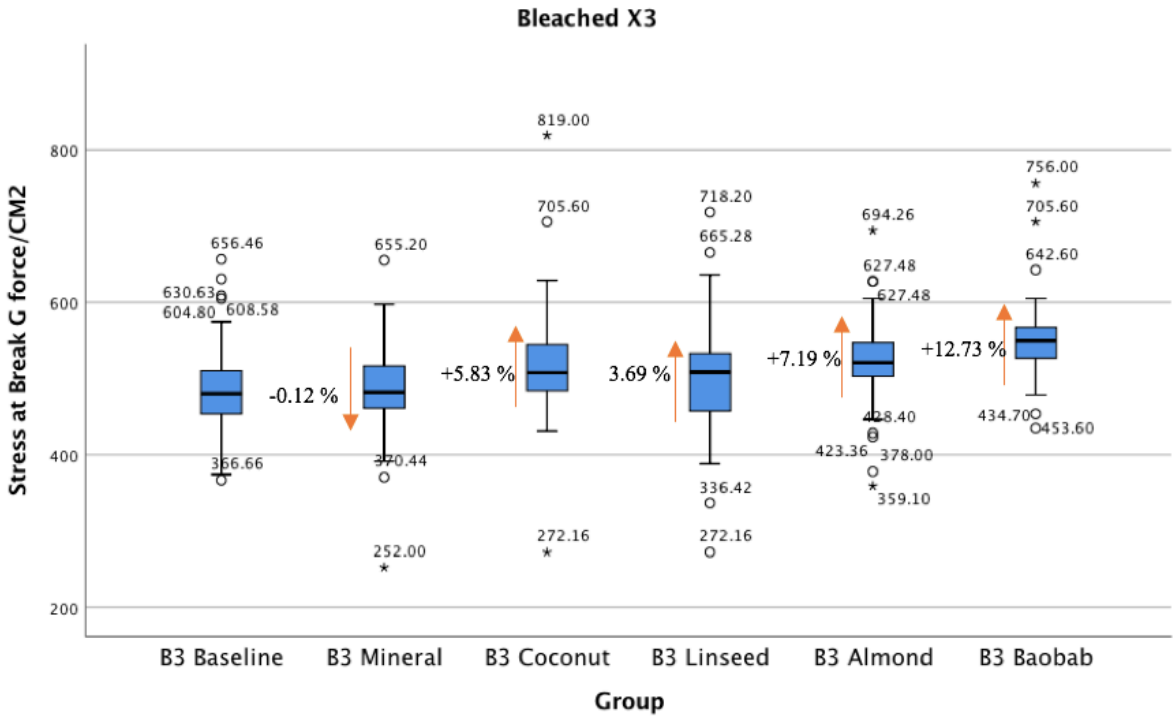


Figure 3-24: Box plot representing stress at break data for bleached x3 hair treated with studied oils

Table 3-43: Statistical analysis of stress at break data for bleached 5 hair baseline and mineral oil treated

	Group	Stress at Break (G-force/cm²) m ± SD	P Value
Bleached 5	Baseline	444,05 ± 53,67	0.815
	Mineral	441.09 ± 64,29	

Means of Bleached x5 Baseline and Bleached x5 Mineral are not statistically different from each other (P>0.05).

Table 3-44: Statistical analysis of stress at break data for bleached 5 hair baseline and coconut oil treated

	Group	Stress at Break (G-force/cm²) m ± SD	P Value
Bleached 5	Baseline	444,05 ± 53,67	0.004
	Coconut	472,23 ± 62,53	

Means of Bleached x5 Baseline and Bleached x5 Coconut are statistically different from each other (P>0.05).

Table 3-45: Statistical analysis of stress at break data for bleached 5 hair baseline and linseed oil treated

	Group	Stress at Break (G-force/cm²) m ± SD	P Value
Bleached 5	Baseline	444,05 ± 53,67	0.007
	Linseed	475,12 ± 57,58	

Means of Bleached x5 Baseline and Bleached x5 Linseed are statistically different from each other (P>0.05).

Table 3-46: Statistical analysis of stress at break data for bleached 5 hair baseline and almond oil treated

	Group	Stress at Break (G-force/cm²) m ± SD	P Value
Bleached 5	Baseline	444,05 ± 53,67	<.001
	Almond	506,76 ± 55,08	

Means of Bleached x5 Baseline and Bleached x5 Almond are statistically different from each other (P>0.05).

Table 3-47: Statistical analysis of stress at break data for bleached 5 hair baseline and baobab oil treated

	Group	Stress at Break (G-force/cm²) m ± SD	P Value
Bleached 5	Baseline	444,05 ± 53,67	<.001
	Baobab	497,73 ± 55,27	

Means of Bleached x5 Baseline and Bleached x5 Baobab are statistically different from each other (P>0.05).

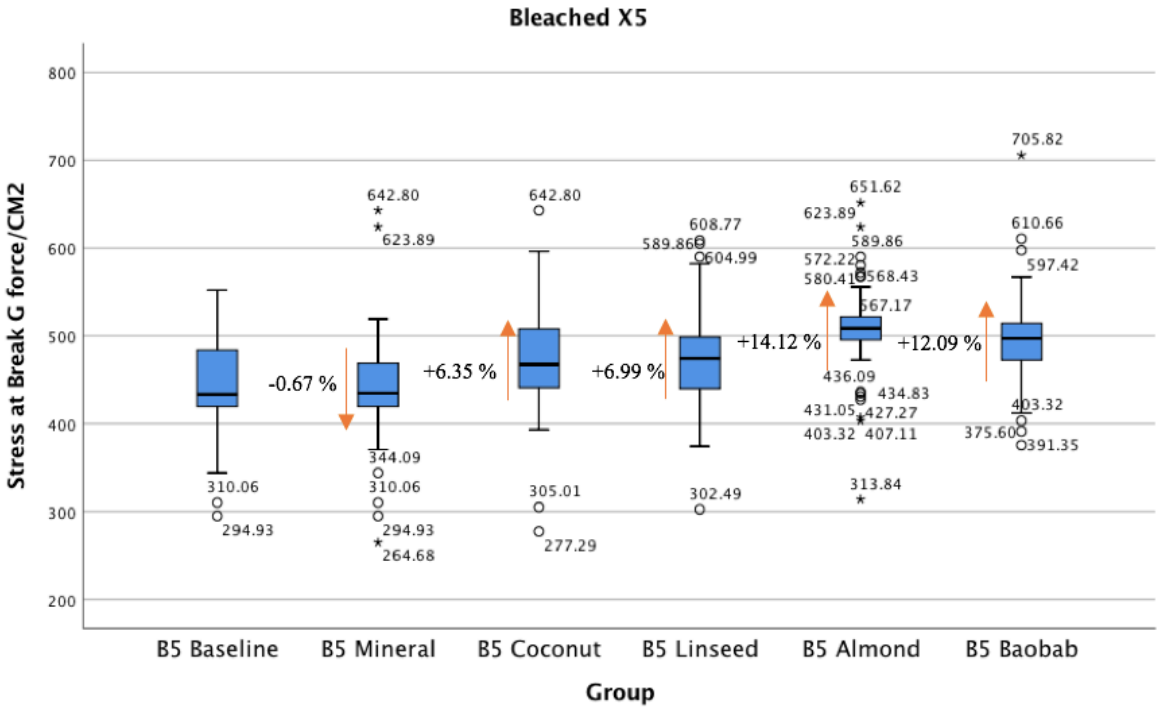


Figure 3-25: Box plot representing stress at break data for bleached x5 hair treated with studied oils

Table 3-48: Statistical analysis of stress at break data for bleached 7 hair baseline and mineral oil treated

	Group	Stress at Break (G-force/cm²) m ± SD	P Value
Bleached 7	Baseline	423,11 ± 65,13	0.013
	Mineral	444.09 ± 48,8	

Means of Bleached x7 Baseline and Bleached x7 Mineral are not statistically different from each other (P>0.05).

Table 3-49: Statistical analysis of stress at break data for bleached 7 hair baseline and coconut oil treated

	Group	Stress at Break (G-force/cm²) m ± SD	P Value
Bleached 7	Baseline	423,11 ± 65,13	0.001
	Coconut	461,42 ± 60,27	

Means of Bleached x7 Baseline and Bleached x7 Coconut are statistically different from each other (P>0.05).

Table 3-50: Statistical analysis of stress at break data for bleached 7 hair baseline and linseed oil treated

	Group	Stress at Break (G-force/cm²) m ± SD	P Value
Bleached 7	Baseline	423,11 ± 65,13	<.001
	Linseed	467,87 ± 66,36	

Means of Bleached x7 Baseline and Bleached x7 Linseed are statistically different from each other (P>0.05).

Table 3-51: Statistical analysis of stress at break data for bleached 7 hair baseline and almond oil treated

	Group	Stress at Break (G-force/cm²) m ± SD	P Value
Bleached 7	Baseline	423,11 ± 65,13	<.001
	Almond	471,19 ± 66,36	

Means of Bleached x7 Baseline and Bleached x7 Almond are statistically different from each other (P>0.05).

Table 3-52: Statistical analysis of stress at break data for bleached 7 hair baseline and baobab oil treated

	Group	Stress at Break (G-force/cm²) m ± SD	P Value
Bleached 7	Baseline	423,11 ± 65,13	<.001
	Baobab	488,59 ± 56,21	

Means of Bleached x7 Baseline and Bleached x7 Baobab are statistically different from each other (P>0.05).

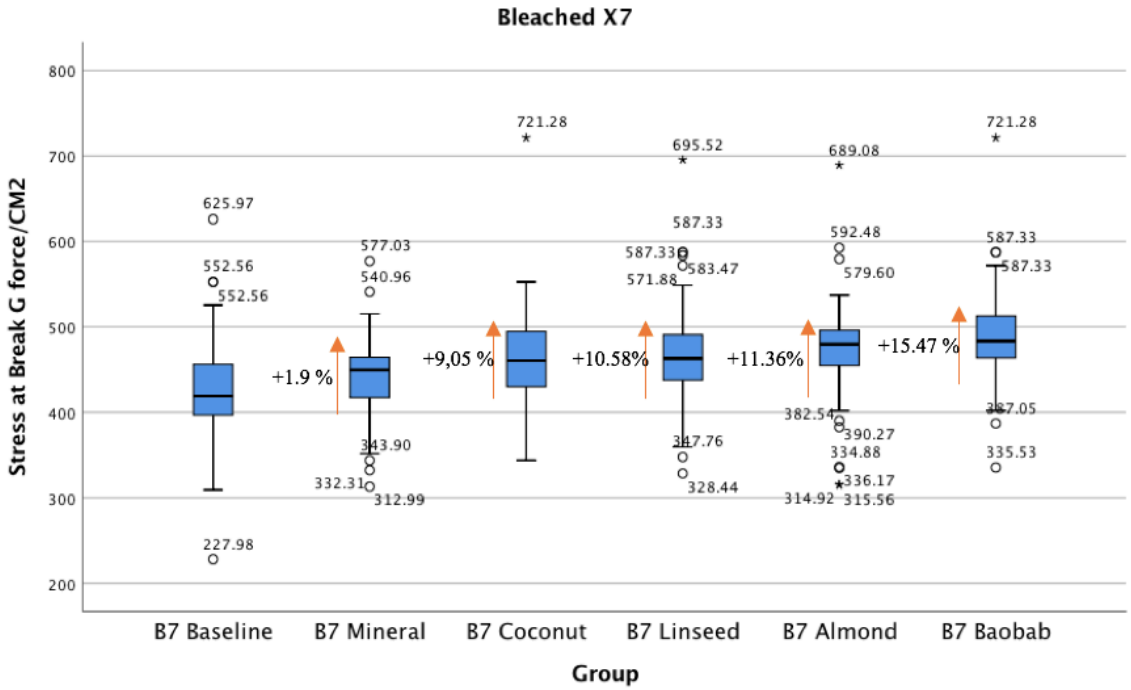


Figure 3-26: Box plot representing stress at break data for bleached x7 hair treated with studied oils

Table 3-53: Stress at break percentage changes for each oil treatment after bleaching

	Virgin	Bleached x1	Bleached x3	Bleached x5	Bleached x7
Baseline	0	-5,09 %	-6,47 %	-14,99 %	-19,00 %
Mineral	0	-0,03 %	-2,97 %	-12,30 %	-11,79 %
Coconut	0	-4,89 %	-5,41 %	-13,61 %	-15,59 %
Linseed	0	-8,23 %	-17,52 %	-22,65 %	-23,83 %
Almond	0	-2,11 %	-3,01 %	-6,15 %	-12,74 %
Baobab	0	3,79 %	3,98 %	-6,04 %	-7,77 %

Table 3-54: Stress at break percentage changes for each oil treatment compared to virgin baseline

	Virgin	Bleached x1	Bleached x3	Bleached x5	Bleached x7
Baseline	0,00	-5,09 %	-6,47 %	-14,99 %	-19,00 %
Mineral	-2,72 %	-3,74 %	-6,58 %	-15,56 %	-14,99 %
Coconut	4,65 %	-0,47 %	-1,01 %	-9,60 %	-11,67 %
Linseed	17,58 %	7,91 %	-3,02 %	-9,05 %	-10,43 %
Almond	3,37 %	1,19 %	0,25 %	-2,99 %	-9,80 %
Baobab	1,41 %	5,25 %	5,44 %	-4,72 %	-6,47 %

3.3 COMBING FORCES

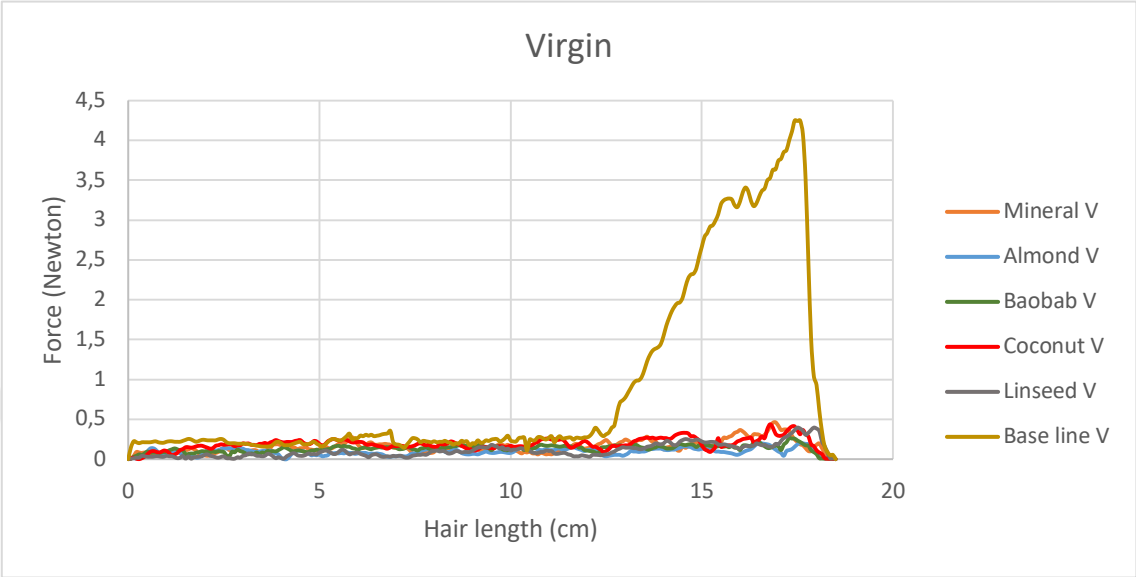


Figure 3-27: Combing forces of virgin hair treated with different oils

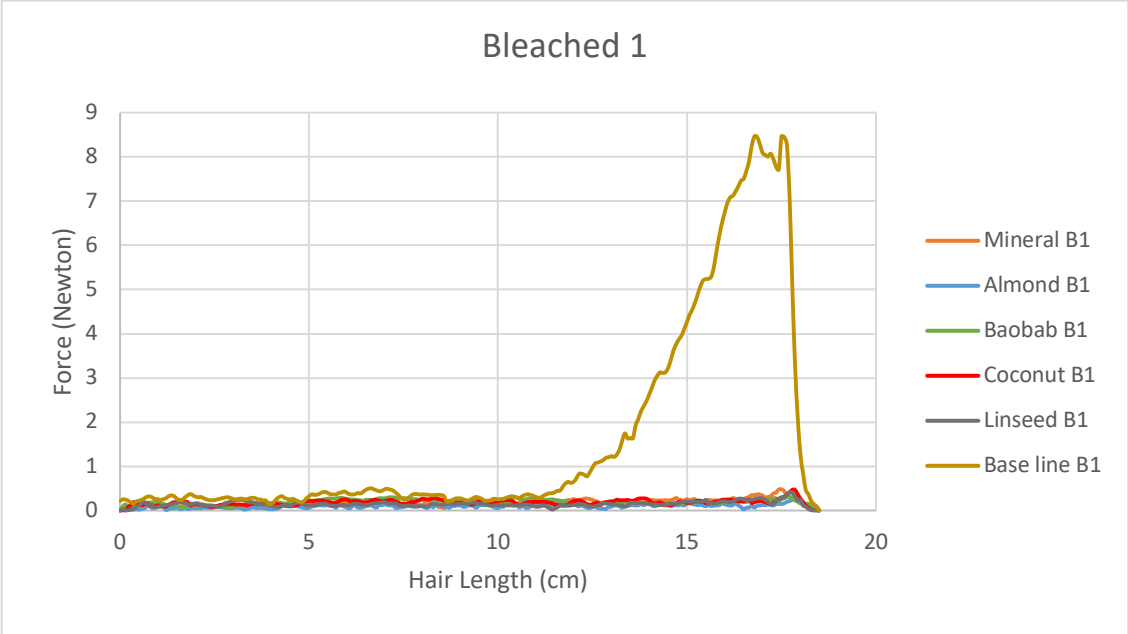


Figure 3-28: Combing forces of bleached 1 hair treated with different oils

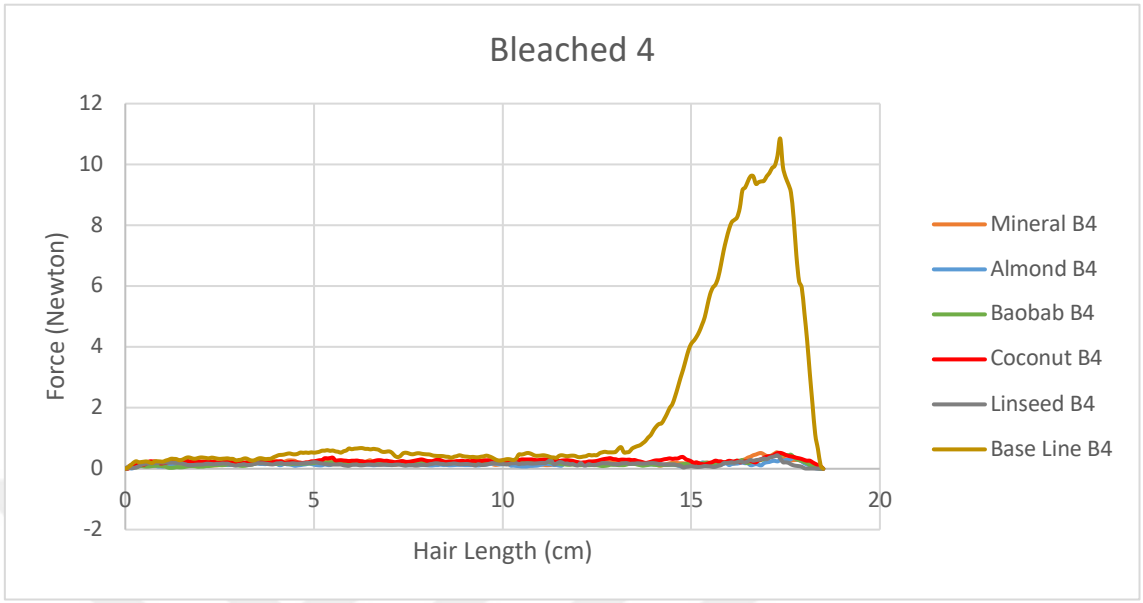


Figure 3-29: Combing forces of bleached x4 hair treated with different oils

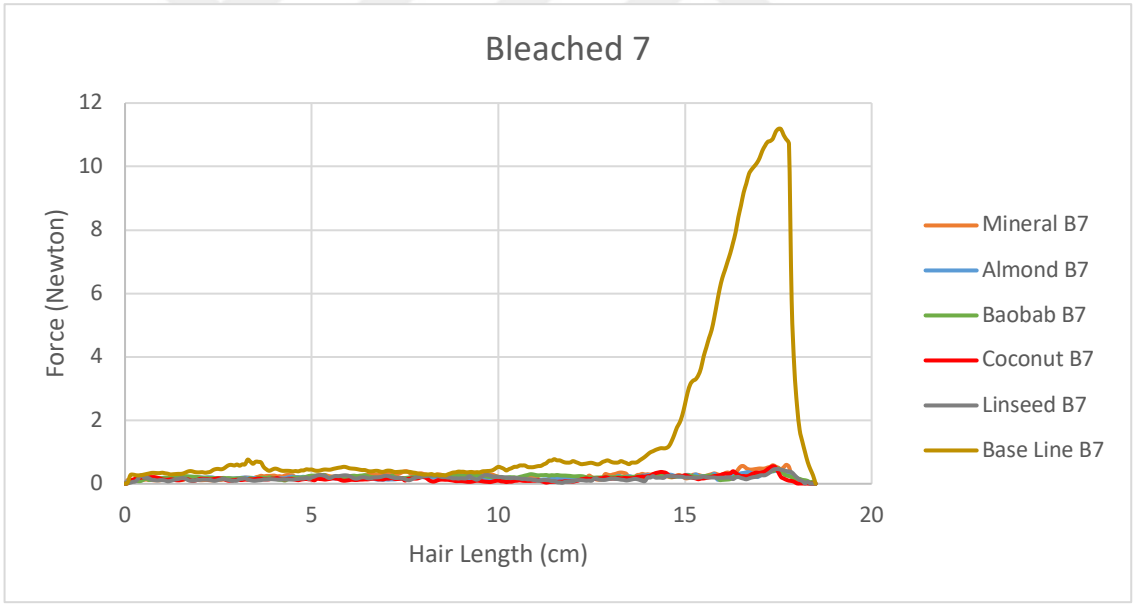


Figure 3-30: Combing forces of bleached x7 hair treated with different oils

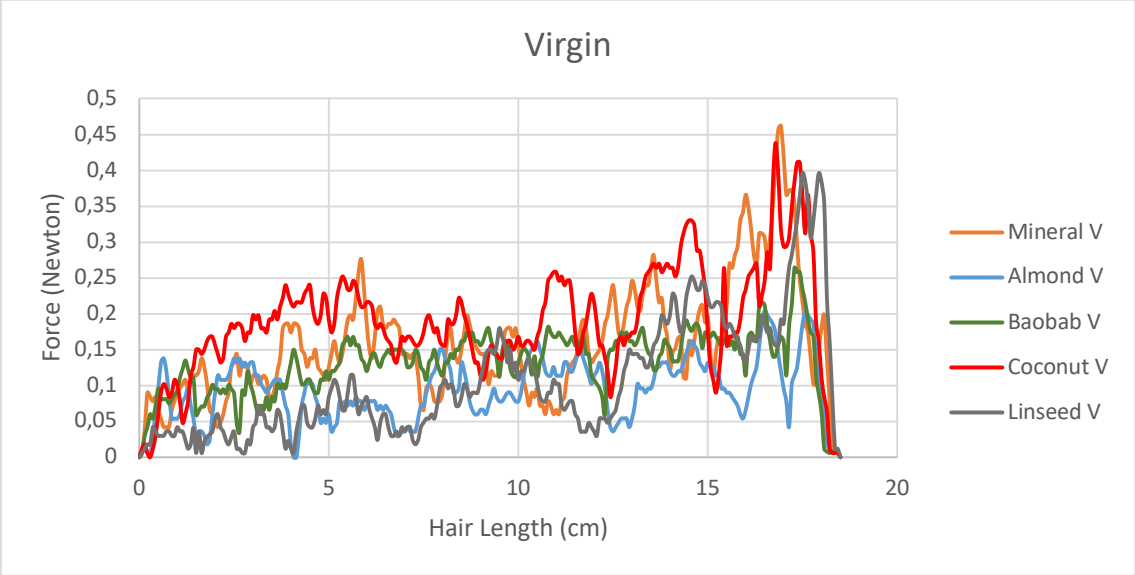


Figure 3-31: Combing forces of virgin hair treated with different oils (No baseline)

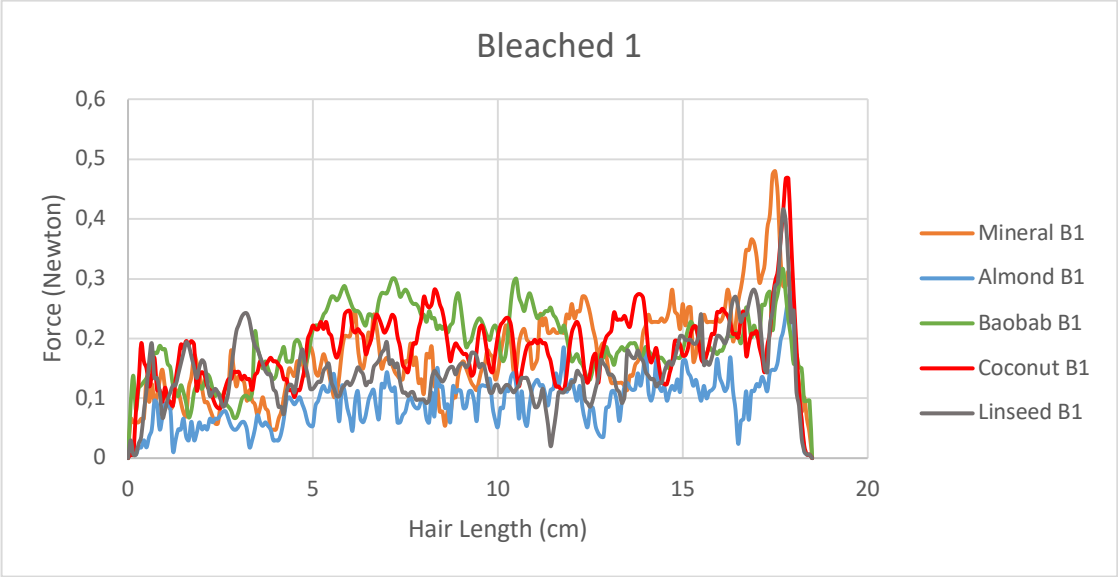
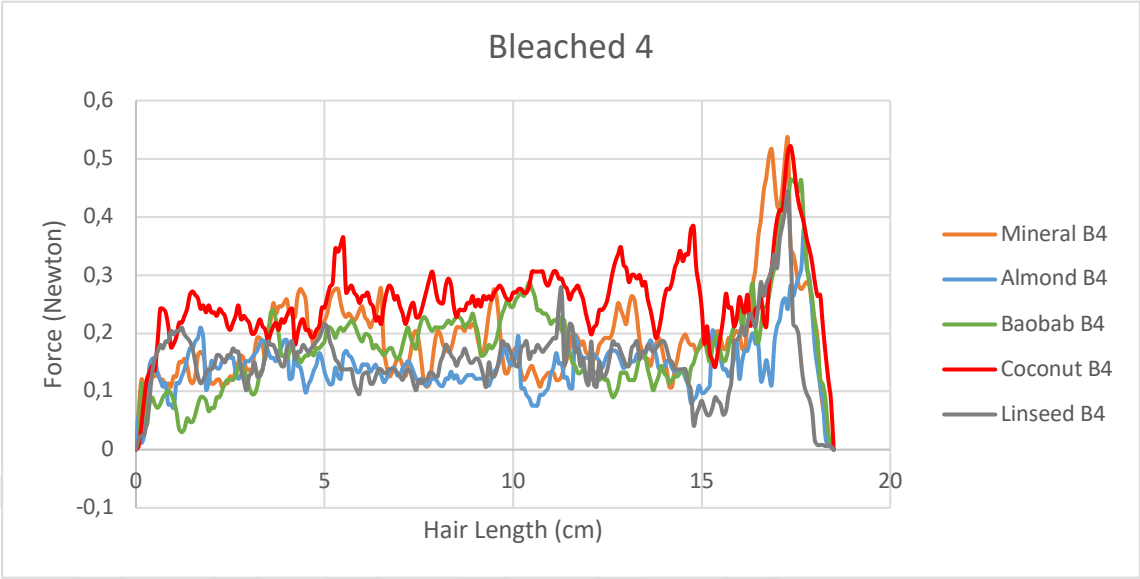


Figure 3-32: Combing forces of bleached x1 hair treated with different oils (No baseline)



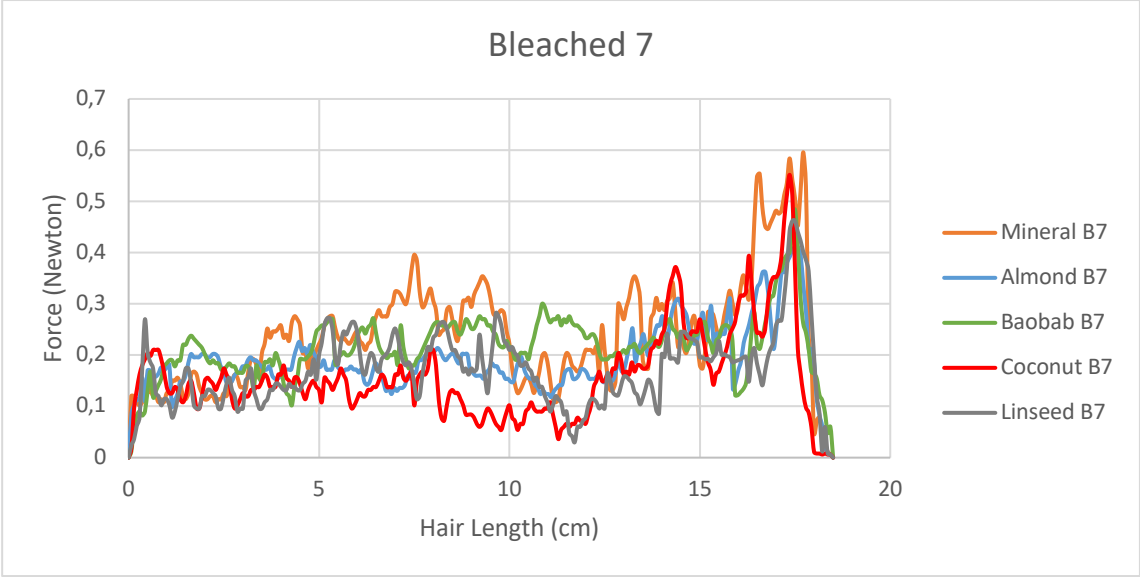


Figure 3-34: Combing forces of bleached x7 hair treated with different oils (No baseline)

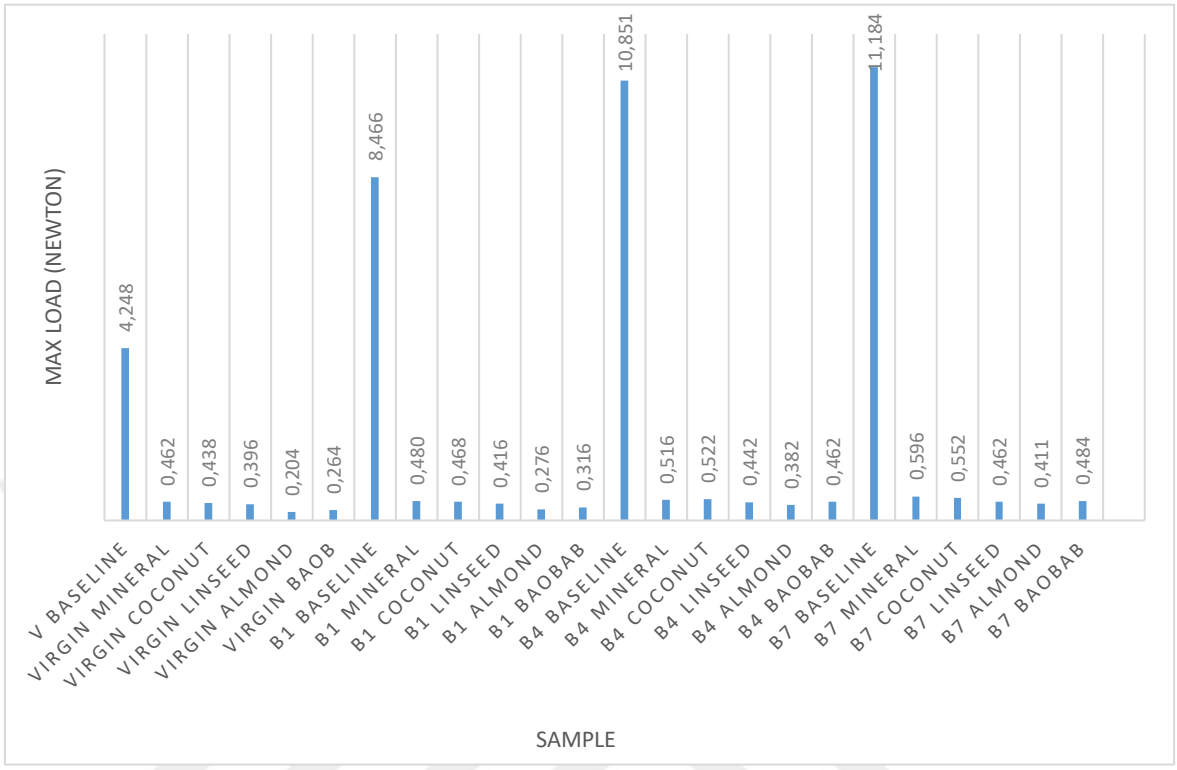


Figure 3-35: Combing forces max load of all studied samples (According to hair type)

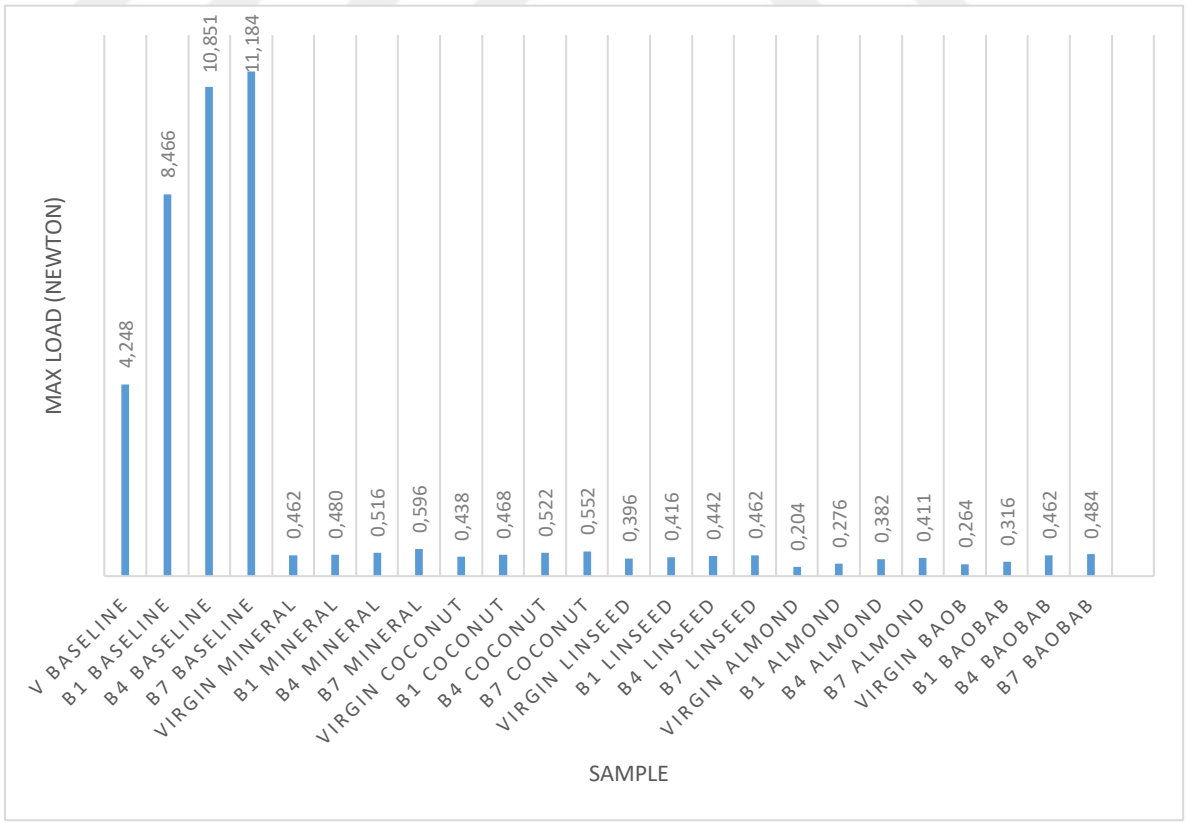


Figure 3-36: Combing forces max load of all studied samples (According to oil treatment)

3.4 GROOMING

3.4.1 Statistical Analysis

Table 3-55: Chi square test data for baseline non treated virgin and bleached samples

Baseline (No Oil Treatment)								P Value
			Virgin	Bleached x1	Bleached x4	Bleached x7	Total	
Cycles	1000	Count	14	16	20	23	73	0,990
		% Within Cycles	19,2%	21,9%	27,4%	31,5%	100,0 %	
		% Within Groups	48,3%	38,1%	39,2%	42,6%	41,5%	
	2000	Count	5	8	13	14	40	
		% Within Cycles	12,5%	20,0%	32,5%	35,0%	100,0 %	
		% Within Groups	17,2%	19,0%	25,5%	5,9%	22,7%	
	3000	Count	4	7	9	8	28	
		% Within Cycles	14,3%	25,0%	32,1%	28,6%	100,0 %	
		% Within Groups	13,8%	16,7%	17,6%	14,8%	15,9%	
	4000	Count	3	7	5	6	21	
		% Within Cycles	14,3%	33,3%	23,8%	28,6%	100,0 %	
		% Within Groups	10,3%	16,7%	9,8%	11,1%	11,9%	
	5000	Count	3	4	4	3	14	
		% Within Cycles	21,4%	28,6%	28,6%	21,4%	100,0 %	
		% Within Groups	10,3%	9,5%	7,8%	5,6%	8,0%	
Total		Count	29	42	51	54	176	
		% Within Cycles	16,5%	23,9%	29,0%	30,7%	100,0 %	
		% Within Groups	100,0 %	100,0%	100,0%	100,0%	100,0 %	

Chi-Square Test

When compared according to type of oil treatment, in Baseline samples, all samples groups (virgin, bleached x1, bleached x4, bleached x7) broken fibers ratio between 1000,2000,3000,4000 and 5000 grooming cycles are not statistically different from each other (P>0,05).

Table 3-56: Chi square test data for mineral oil treated virgin and bleached samples

Mineral Oil								P Value
			Virgin	Bleached x1	Bleached x4	Bleached x7	Total	
Cycles	1000	Count	9	12	14	15	50	0,999
		% Within Cycles	18,0%	24,0%	28,0%	30,0%	100,0 %	
		% Within Groups	47,4%	46,2%	40,0%	39,5%	42,4%	
	2000	Count	5	6	8	11	30	
		% Within Cycles	16,7%	20,0%	26,7%	36,7%	100,0 %	
		% Within Groups	26,3%	23,1%	22,9%	28,9%	25,4%	
	3000	Count	3	3	7	5	18	
		% Within Cycles	16,7%	16,7%	38,9%	27,8%	100,0 %	
		% Within Groups	15,8%	11,5%	20,0%	13,2%	15,3%	
	4000	Count	1	3	4	4	12	
		% Within Cycles	8,3%	25,0%	33,3%	33,3%	100,0 %	
		% Within Groups	5,3%	11,5%	11,4%	10,5%	10,2%	
	5000	Count	1	2	2	3	8	
		% Within Cycles	12,5%	5,0%	25,0%	37,5%	100,0 %	
		% Within Groups	5,3%	7,7,%	5,7%	7,9%	6,8%	
Total		Count	19	26	35	38	118	
		% Within Cycles	16,1%	22,0%	29,7%	32,2%	100,0 %	
		% Within Groups	100,0 %	100,0%	100,0%	100,0%	100,0 %	

Chi-Square test

When compared according to type of oil treatment, in Mineral oil treated samples, all samples groups (virgin, bleached x1, bleached x4, bleached x7) broken fibers ratio between 1000,2000,3000,4000 and 5000 grooming cycles are not statistically different from each other (P>0,05).

Table 3-57: Chi square test data for coconut oil treated virgin and bleached samples

Coconut Oil								P Value
			Virgin	Bleached x1	Bleached x4	Bleached x7	Total	
Cycles	1000	Count	8	11	13	13	45	0,984
		% Within Cycles	17,8%	24,4%	28,9%	28,9%	100,0 %	
		% Within Groups	47,1%	44,0%	39,4%	38,2%	41,3%	
	2000	Count	3	4	8	10	25	
		% Within Cycles	12,0%	16,0%	32,0%	40,0%	100,0 %	
		% Within Groups	17,6%	16,0%	24,2%	29,4%	22,9%	
	3000	Count	3	5	5	5	18	
		% Within Cycles	16,7%	27,8%	27,8%	27,8%	100,0 %	
		% Within Groups	17,6%	20,0%	15,2%	14,7%	16,5%	
	4000	Count	1	4	4	3	12	
		% Within Cycles	8,3%	33,3%	33,3%	25,0%	100,0 %	
		% Within Groups	5,9%	16,0%	12,1%	8,8%	11,0%	
	5000	Count	2	1	3	3	9	
		% Within Cycles	22,2%	11,1%	33,3%	33,3%	100,0 %	
		% Within Groups	11,8%	4,0%	9,1%	8,8%	8,3%	
Total		Count	17	25	33	34	109	
		% Within Cycles	15,5%	22,9%	30,3%	31,2%	100,0 %	
		% Within Groups	100,0 %	100,0%	100,0%	100,0%	100,0 %	

Chi-Square test

When compared according to type of oil treatment, in Coconut oil treated samples, all samples groups (virgin, bleached x1, bleached x4, bleached x7) broken fibers ratio between 1000,2000,3000,4000 and 5000 grooming cycles are not statistically different from each other (P>0,05).

Table 3-58: Chi square test data for linseed oil treated virgin and bleached samples

Linseed Oil								P Value
			Virgin	Bleached x1	Bleached x4	Bleached x7	Total	
Cycles	1000	Count	8	12	13	14	47	0,999
		% Within Cycles	17,0%	25,5%	27,7%	29,8%	100,0 %	
		% Within Groups	44,4%	46,2%	38,2%	41,2%	41,3%	
	2000	Count	3	5	9	9	26	
		% Within Cycles	11,5%	19,2%	34,6%	34,6%	100,0 %	
		% Within Groups	16,7%	192,0%	26,5%	25,0%	22,8%	
	3000	Count	3	4	5	6	18	
		% Within Cycles	16,7%	22,2%	27,8%	33,3%	100,0 %	
		% Within Groups	16,7%	15,4%	14,7%	16,7%	15,8%	
	4000	Count	2	4	5	4	15	
		% Within Cycles	13,3%	26,7%	33,3%	26,7%	100,0 %	
		% Within Groups	11,1%	15,4%	14,7%	11,1%	13,2%	
	5000	Count	2	1	2	3	8	
		% Within Cycles	25,0%	12,5%	25,0%	37,5%	100,0 %	
		% Within Groups	11,1%	3,8%	5,9%	8,3%	7,0%	
Total		Count	18	26	34	36	114	
		% Within Cycles	15,8%	22,8%	29,8%	31,6%	100,0 %	
		% Within Groups	100,0 %	100,0%	100,0%	100,0%	100,0 %	

Chi-Square test

When compared according to type of oil treatment, in Linseed oil treated samples, all samples groups (virgin, bleached x1, bleached x4, bleached x7) broken fibers ratio between 1000,2000,3000,4000 and 5000 grooming cycles are not statistically different from each other (P>0,05).

Table 3-59: Chi square test data for almond oil treated virgin and bleached samples

Almond Oil								P Value
			Virgin	Bleached x1	Bleached x4	Bleached x7	Total	
Cycles	1000	Count	7	10	11	13	41	0,996
		% Within Cycles	17,1%	24,4%	6,8%	31,7%	100,0 %	
		% Within Groups	46,7%	47,6%	35,5%	38,2%	40,6%	
	2000	Count	3	6	8	8	25	
		% Within Cycles	12,0%	24,0%	32,0%	32,0%	100,0 %	
		% Within Groups	20,0%	28,6%	25,8%	23,5%	24,8%	
	3000	Count	2	3	5	7	17	
		% Within Cycles	11,8%	17,6%	29,4%	41,2%	100,0 %	
		% Within Groups	13,3%	14,3%	16,1%	20,6%	16,8%	
	4000	Count	2	1	5	4	12	
		% Within Cycles	16,7%	8,3%	41,7%	33,3%	100,0 %	
		% Within Groups	13,3%	4,8%	16,1%	11,8%	11,9%	
	5000	Count	1	1	2	2	6	
		% Within Cycles	16,7%	16,7%	33,3%	33,3%	100,0 %	
		% Within Groups	6,7%	4,8%	6,5%	5,9%	5,9%	
Total		Count	15	21	31	34	101	
		% Within Cycles	14,9%	20,8%	30,7%	33,7%	100,0 %	
		% Within Groups	100,0 %	100,0%	100,0%	100,0%	100,0 %	

Chi-Square test

When compared according to type of oil treatment, in Almond oil treated samples, all samples groups (virgin, bleached x1, bleached x4, bleached x7) broken fibers ratio between 1000,2000,3000,4000 and 5000 grooming cycles are not statistically different from each other (P>0,05).

Table 3-60: Chi square test data for baobab oil treated virgin and bleached samples

			Baobab Oil					P Value
			Virgin	Bleached x1	Bleached x4	Bleached x7	Total	
Cycles	1000	Count	7	11	12	13	43	1,000
		% Within Cycles	16,3%	25,6%	27,9%	30,2%	100,0 %	
		% Within Groups	41,2%	44,0%	37,5%	37,1%	39,4%	
	2000	Count	5	5	8	9	27	
		% Within Cycles	18,5%	18,5%	29,6%	33,3%	100,0 %	
		% Within Groups	29,4%	20,0%	25,0%	25,7%	24,8%	
	3000	Count	2	5	5	6	18	
		% Within Cycles	11,1%	27,8%	27,8%	33,3%	100,0 %	
		% Within Groups	11,8%	20,0%	15,6%	17,1%	16,5%	
	4000	Count	2	3	5	4	14	
		% Within Cycles	14,3%	21,4%	35,7%	28,6%	100,0 %	
		% Within Groups	11,8%	12,0%	15,6%	11,4%	12,8%	
	5000	Count	1	1	2	3	7	
		% Within Cycles	14,3%	14,3%	28,6%	42,9%	100,0 %	
		% Within Groups	5,9%	4,0%	6,3%	60,0%	6,4%	
Total		Count	17	25	32	35	109	
		% Within Cycles	15,6%	22,9%	294,0%	32,1%	100,0 %	
		% Within Groups	100,0 %	100,0%	100,0%	100,0%	100,0 %	

Chi-Square test

When compared according to type of oil treatment, in Baobab oil treated samples, all samples groups (virgin, bleached x1, bleached x4, bleached x7) broken fibers ratio between 1000,2000,3000,4000 and 5000 grooming cycles are not statistically different from each other (P>0,05).

Table 3-61: Chi square test data for virgin hair treated with different oils

Virgin Hair										P Value
			Baseline	Mineral	Coconut	Linseed	Baobab	Almond	Total	1,000
Cycles	1000	Count	14	9	8	8	7	7	53	
		% Within Cycles	26,4%	17,0%	15,1%	15,1%	13,2%	13,2%	100,0%	
		% Within Groups	48,3%	47,4%	47,1%	44,4%	41,2%	46,7%	46,1%	
	2000	Count	5	5	3	3	5	3	24	
		% Within Cycles	20,8%	20,8%	12,5%	12,5%	20,8%	12,5%	100,0%	
		% Within Groups	17,2%	26,3%	17,6%	16,7%	29,4%	20,0%	20,9%	
	3000	Count	4	3	3	3	2	2	17	
		% Within Cycles	23,5%	17,6%	17,6%	17,6%	11,8%	11,8%	100,0%	
		% Within Groups	13,8%	15,8%	17,6%	16,7%	11,8%	13,3%	14,8%	
	4000	Count	3	1	1	2	2	2	11	
		% Within Cycles	27,3%	9,1%	9,1%	18,2%	18,2%	18,2%	100,0%	
		% Within Groups	10,3%	5,3%	5,9%	11,1%	11,8%	13,3%	9,6%	
	5000	Count	3	1	2	2	1	1	10	
		% Within Cycles	30,0%	10,0%	20,0%	20,0%	10,0%	10,0%	100,0%	
		% Within Groups	10,3%	5,3%	11,8%	11,1%	5,9%	6,7%	8,7%	
Total		Count	29	19	17	18	17	15	115	
		% Within Cycles	25,2%	16,5%	14,8%	15,7%	14,8%	13,0%	100,0%	
		% Within Groups	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	

Chi-Square test

When compared according to type of treated hair, in Virgin hair treated samples, all samples groups (non-treated hair, mineral, coconut, linseed, baobab, and almond treated hair) broken fibers ratio between 1000,2000,3000,4000 and 5000 grooming cycles are not statistically different from each other (P>0,05).

Table 3-62: Chi square test data for bleached x1 hair treated with different oils

Bleached x1										P Value
			Baseline	Mineral	Coconut	Linseed	Baobab	Almond	Total	
Cycles	1000	Count	16	12	11	12	11	10	72	0,999
		% Within Cycles	22,2%	16,7%	15,3%	16,7%	15,3%	13,9%	100,0%	
		% Within Groups	38,1%	46,2%	44,0%	46,2%	44,0%	47,6%	43,6%	
	2000	Count	8	6	4	5	5	6	34	
		% Within Cycles	23,5%	17,6%	11,8%	14,7%	14,7%	17,6%	100,0%	
		% Within Groups	19,0%	23,1%	16,0%	19,2%	20,0%	28,6%	20,6%	
	3000	Count	7	3	5	4	5	3	27	
		% Within Cycles	25,9%	11,1%	18,5%	14,8%	18,5%	11,1%	100,0%	
		% Within Groups	16,7%	11,5%	16,0%	15,4%	12,0%	4,8%	13,3%	
	4000	Count	7	3	4	4	3	1	22	
		% Within Cycles	31,8%	13,6%	18,2%	18,2%	13,6%	4,5%	100,0%	
		% Within Groups	16,7%	11,5%	16,0%	15,4%	12,0%	4,8%	13,3%	
	5000	Count	4	2	1	1	1	1	10	
		% Within Cycles	40,0%	20,0%	10,0%	10,0%	10,0%	10,0%	100,0%	
		% Within Groups	9,5%	7,7%	4,0%	3,8%	4,0%	4,8%	6,1%	
Total		Count	42	26	25	26	25	21	165	
		% Within Cycles	25,5%	15,8%	15,2%	15,8%	15,2%	12,7%	100,0%	
		% Within Groups	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	

Chi-Square test

When compared according to type of treated hair, in Bleached x1 hair treated samples, all samples groups (non-treated hair, mineral, coconut, linseed, baobab, and almond treated hair) broken fibers ratio between 1000,2000,3000,4000 and 5000 grooming cycles are not statistically different from each other (P>0,05).

Table 3-63: Chi square test data for bleached x4 hair treated with different oils

			Bleached x4							P Value
			Baseline	Mineral	Coconut	Linseed	Baobab	Almond	Total	
Cycles	1000	Count	20	14	13	13	12	11	83	1,000
		% Within Cycles	24.1%	16.9%	15.7%	15.7%	14.5%	13.3%	100.0%	
		% Within Groups	39.2%	40.0%	39.4%	38.2%	37.5%	35.5%	38.4%	
	2000	Count	13	8	8	9	8	8	54	
		% Within Cycles	24.1%	14.8%	14.8%	16.7%	14.8%	14.8%	100.0%	
		% Within Groups	25.5%	22.9%	24.2%	26.5%	25.0%	25.8%	25.0%	
	3000	Count	9	7	5	5	5	5	36	
		% Within Cycles	25.0%	19.4%	13.9%	13.9%	13.9%	13.9%	100.0%	
		% Within Groups	17.6%	20.0%	15.2%	14.7%	15.6%	16.1%	16.7%	
	4000	Count	5	4	4	5	5	5	28	
		% Within Cycles	17.9%	14.3%	14.3%	17.9%	17.9%	17.9%	100.0%	
		% Within Groups	9.8%	11.4%	12.1%	14.7%	15.6%	16.1%	13.0%	
	5000	Count	4	2	3	2	2	2	15	
		% Within Cycles	26.7%	13.3%	20.0%	13.3%	13.3%	13.3%	100.0%	
		% Within Groups	7.8%	5.7%	9.1%	5.9%	6.3%	6.5%	6.9%	
Total		Count	51	35	33	34	32	31	216	
		% Within Cycles	23.6%	16.2%	15.3%	15.7%	14.8%	14.4%	100.0%	
		% Within Groups	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	

Chi-Square test

When compared according to type of treated hair, in Bleached x4 hair treated samples, all samples groups (non-treated hair, mineral, coconut, linseed, baobab, and almond treated hair) broken fibers ratio between 1000,2000,3000,4000 and 5000 grooming cycles are not statistically different from each other (P>0,05).

Table 3-64: Chi square test data for bleached x7 hair treated with different oils

Bleached x7										P Value
			Baseline	Mineral	Coconut	Linseed	Baobab	Almond	Total	
Cycles	1000	Count	23	15	13	14	13	13	91	1,000
		% Within Cycles	25.3%	16.5%	14.3%	15.4%	14.3%	14.3%	100.0%	
		% Within Groups	42.6%	39.5%	38.2%	38.9%	37.1%	38.2%	39.4%	
	2000	Count	14	11	10	9	9	8	61	
		% Within Cycles	23.0%	18.0%	16.4%	14.8%	14.8%	13.1%	100.0%	
		% Within Groups	25.9%	28.9%	29.4%	25.0%	25.7%	23.5%	26.4%	
	3000	Count	8	5	5	6	6	7	37	
		% Within Cycles	21.6%	13.5%	13.5%	16.2%	16.2%	18.9%	100.0%	
		% Within Groups	14.8%	13.2%	14.7%	16.7%	17.1%	20.6%	16.0%	
	4000	Count	6	4	3	4	4	4	25	
		% Within Cycles	24.0%	16.0%	12.0%	16.0%	16.0%	16.0%	100.0%	
		% Within Groups	11.1%	10.5%	8.8%	11.1%	11.4%	11.8%	10.8%	
	5000	Count	3	3	3	3	3	2	17	
		% Within Cycles	17.6%	17.6%	17.6%	17.6%	17.6%	11.8%	100.0%	
		% Within Groups	5.6%	7.9%	8.8%	8.3%	8.6%	5.9%	7.4%	
Total		Count	54	38	34	36	35	34	231	
		% Within Cycles	23.4%	16.5%	14.7%	15.6%	15.2%	14.7%	100.0%	
		% Within Groups	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	

Chi-Square test

When compared according to type of treated hair, in Bleached x7 hair treated samples, all samples groups (non-treated hair, mineral, coconut, linseed, baobab, and almond treated hair) broken fibers ratio between 1000,2000,3000,4000 and 5000 grooming cycles are not statistically different from each other (P>0,05).

3.4.2 Weight of Hair Fibers

Table 3-65: Weight of 10 sets of hair each contains 100 fibers

Set	Weight (g)	Average	Standard Deviation
1	0,108	0,111	0,00597
2	0,119		
3	0,111		
4	0,104		
5	0,114		
6	0,109		
7	0,11		
8	0,113		
9	0,101		
10	0,12		

The following table illustrates typical data obtained from repeated grooming experience for all used hair samples untreated and treated with used oils after 5000 brushing strokes. Figure 3-12 shows a comparison between total broken fibers after 5000 brushing strokes for all used hair samples untreated and treated with used oils. Results clarifies the benefit of using these oils on hair, as the breakage of hair was clearly reduced for all used oils, with some differences between different oils. Nevertheless, more detailed information can be obtained by further analyzing the results as below.

Table 3-66: Typical repeated grooming data for all samples after 5000 brushing strokes

	Baseline				Mineral Oil				Coconut Oil				Linseed Oil				Almond Oil				Baobab Oil			
Cylces	V	B x1	B x4	B x7	V	B x1	B x4	B x7	V	B x1	B x4	B x7	V	B x1	B x4	B x7	V	B x1	B x4	B x7	V	B x1	B x4	B x7
1000	14	16	20	23	9	12	14	15	8	11	13	13	8	12	13	14	7	10	11	13	7	11	12	13
2000	5	8	13	14	5	6	8	11	3	4	8	10	3	5	9	9	3	6	8	8	5	5	8	9
3000	4	7	9	8	3	3	7	5	3	5	5	5	3	4	5	6	2	3	5	7	2	5	5	6
4000	3	7	5	6	1	3	4	4	1	4	4	3	2	4	5	4	2	1	5	4	2	3	5	4
5000	3	4	4	3	1	2	2	3	2	1	3	3	2	1	2	3	1	1	2	2	1	1	2	3
Total	29	42	51	54	19	26	35	38	17	25	33	34	18	26	34	36	15	21	31	34	17	25	32	35

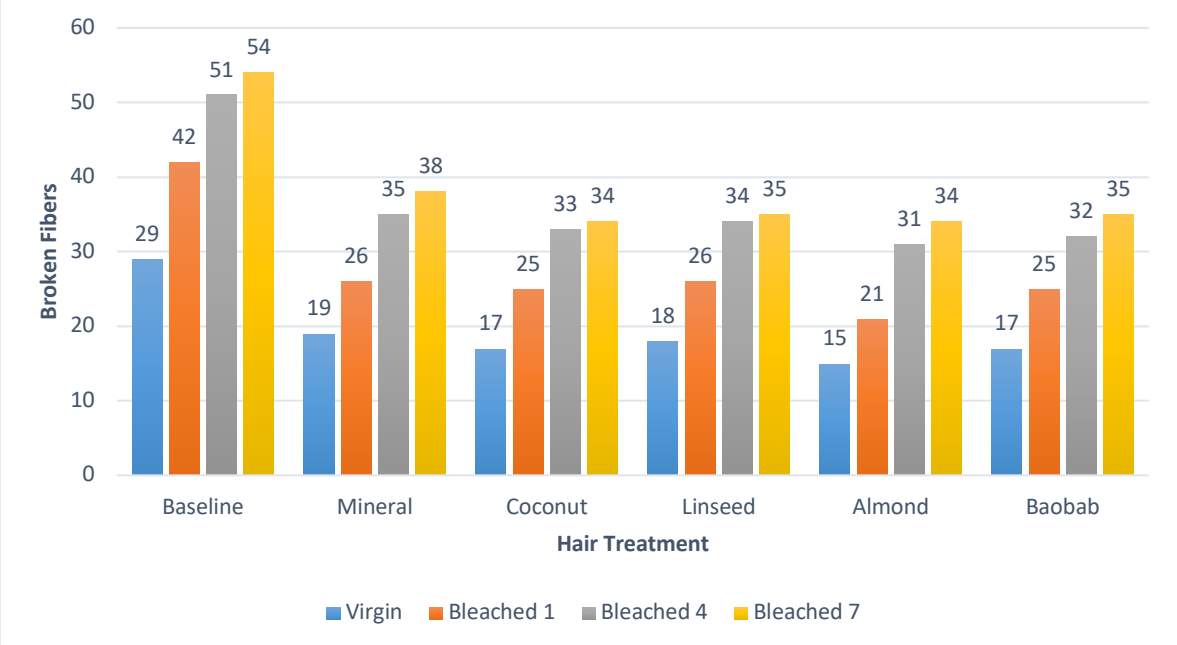


Figure 3-37: Total broken fibers after 5000 brushing strokes according to type of oil treatment

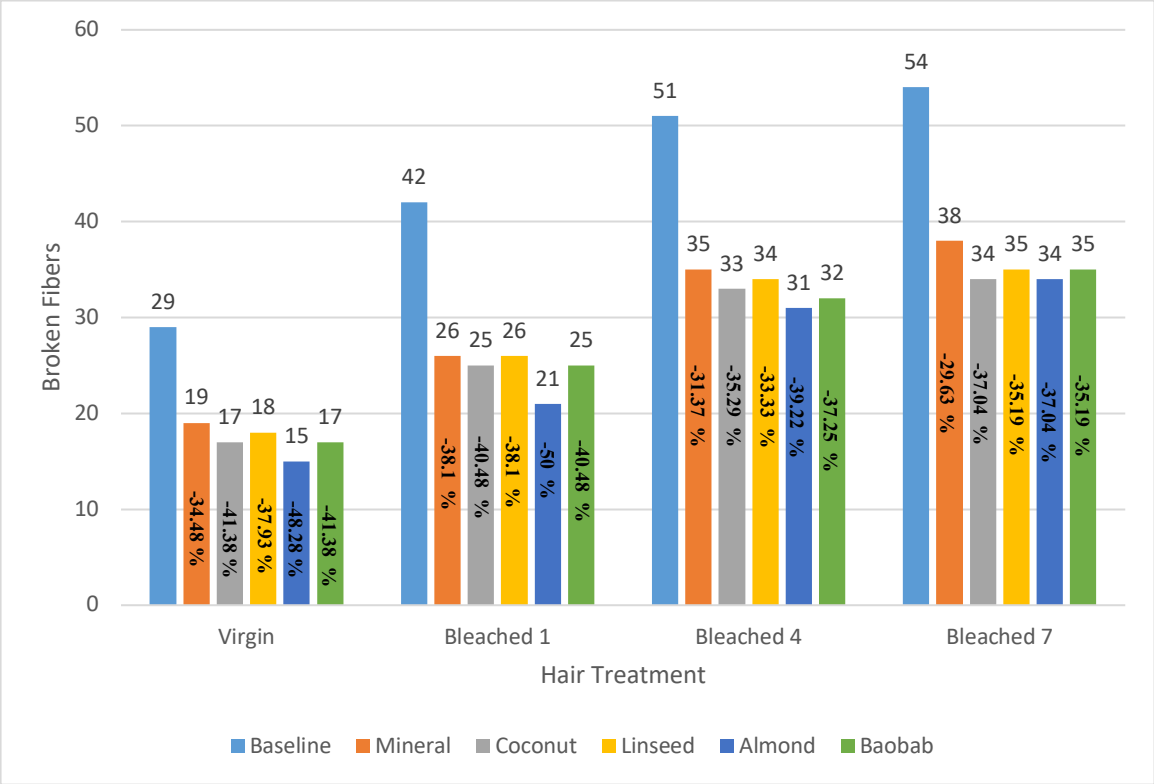


Figure 3-38: Total broken fibers after 5000 brushing strokes according to type of hair

Figures 3-39 through 3-62 illustrates survival probability plots that can expect the possibility of hair fibers breakage as a function of brushing cycle over the range of the experiment.

Table 3-67: Survival probability and breakage likelihood calculation for virgin non-treated hair after 5000 grooming cycles

Baseline					
Brushing Stroke	Total Fibers in Swatch	Fibers Broken	Non-Broken	Survival Probability	Breakage Likelihood
0	2700	0	3000	1,000	0,00%
1000	2700	14	2686	0,995	0,52%
2000	2686	5	2681	0,993	0,70%
3000	2681	4	2677	0,991	0,85%
4000	2677	3	2674	0,990	0,96%
5000	2674	3	2671	0,989	1,07%

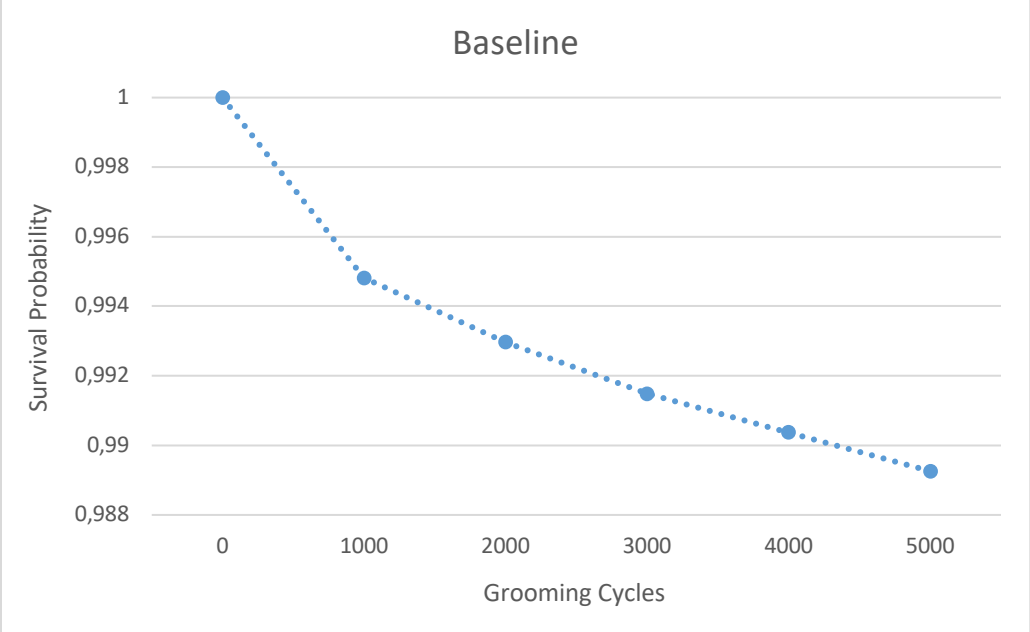


Figure 3-39: Survival probability curve for non-treated virgin hair after 5000 grooming cycles

Table 3-68: Survival probability and breakage likelihood calculation for virgin hair treated with mineral oil after 5000 grooming cycles

Mineral Oil					
Brushing Stroke	Total Fibers in Swatch	Fibers Broken	Non-Broken	Survival Probability	Breakage Likelihood
0	2700	0	3000	1,000	0,00%
1000	2700	9	2691	0,997	0,33%
2000	2691	5	2686	0,995	0,52%
3000	2686	3	2683	0,994	0,63%
4000	2683	1	2682	0,993	0,67%
5000	2682	1	2681	0,993	0,70%

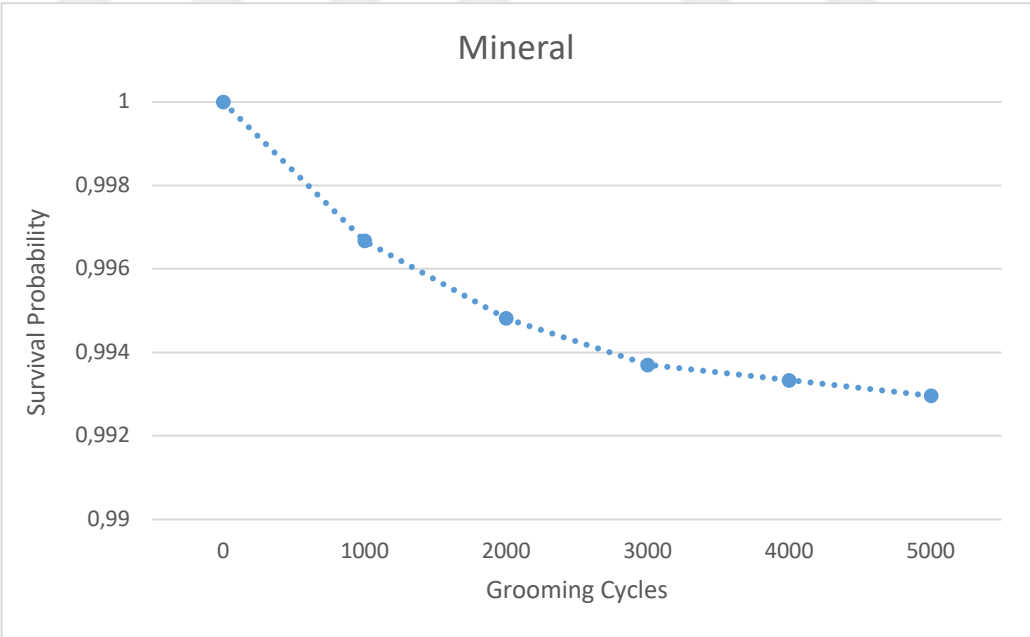


Figure 3-40: Survival probability curve for mineral oil treated virgin hair after 5000 grooming cycles

Table 3-69: Survival probability and breakage likelihood calculation for virgin hair treated with coconut oil after 5000 grooming cycles

Coconut Oil					
Brushing Stroke	Total Fibers in Swatch	Fibers Broken	Non-Broken	Survival Probability	Breakage Likelihood
0	2700	0	3000	1,000	0,00%
1000	2700	8	2692	0,997	0,30%
2000	2692	3	2689	0,996	0,41%
3000	2689	3	2686	0,995	0,52%
4000	2686	1	2685	0,994	0,56%
5000	2685	2	2683	0,994	0,63%

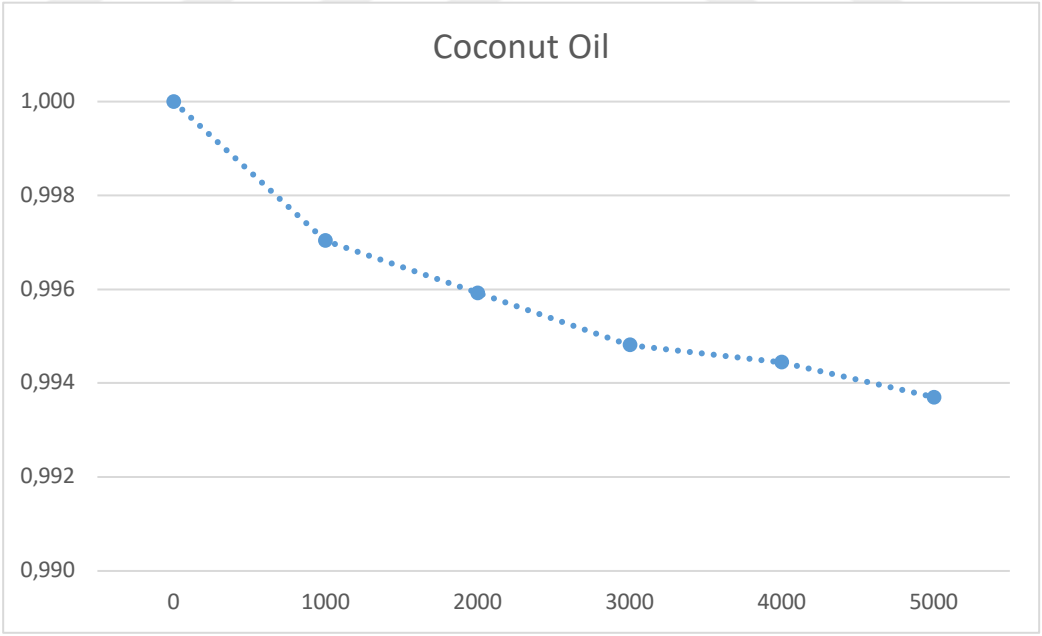


Figure 3-41: Survival probability curve for coconut oil treated virgin hair after 5000 grooming cycles

Table 3-70: Survival probability and breakage likelihood calculation for virgin hair treated with linseed oil after 5000 grooming cycles

Linseed Oil					
Brushing Stroke	Total Fibers in Swatch	Fibers Broken	Non-Broken	Survival Probability	Breakage Likelihood
0	2700	0	3000	1,000	0,00%
1000	2700	8	2692	0,997	0,30%
2000	2692	3	2689	0,996	0,41%
3000	2689	3	2686	0,995	0,52%
4000	2686	2	2684	0,994	0,59%
5000	2684	2	2682	0,993	0,67%

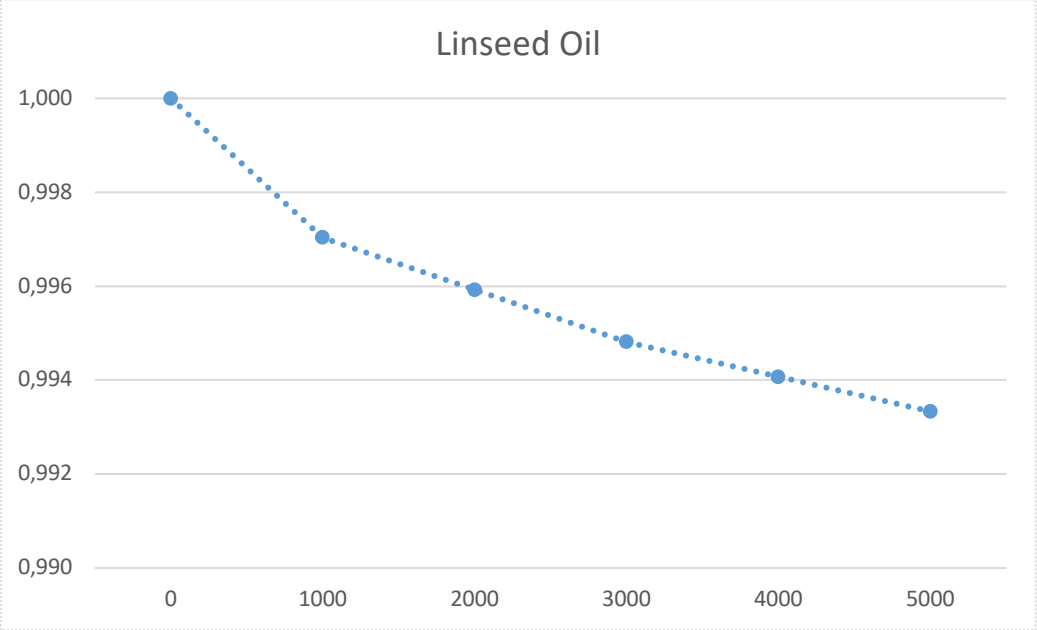


Figure 3-42: Survival probability curve for linseed oil treated virgin hair after 5000 grooming cycles

Table 3-71: Survival probability and breakage likelihood calculation for virgin hair treated with almond oil after 5000 grooming cycles

Almond Oil					
Brushing Stroke	Total Fibers in Swatch	Fibers Broken	Non-Broken	Survival Probability	Breakage Likelihood
0	2700	0	3000	1,000	0,00%
1000	2700	7	2693	0,997	0,26%
2000	2693	3	2690	0,996	0,37%
3000	2690	2	2688	0,996	0,44%
4000	2688	2	2686	0,995	0,52%
5000	2686	1	2685	0,994	0,56%

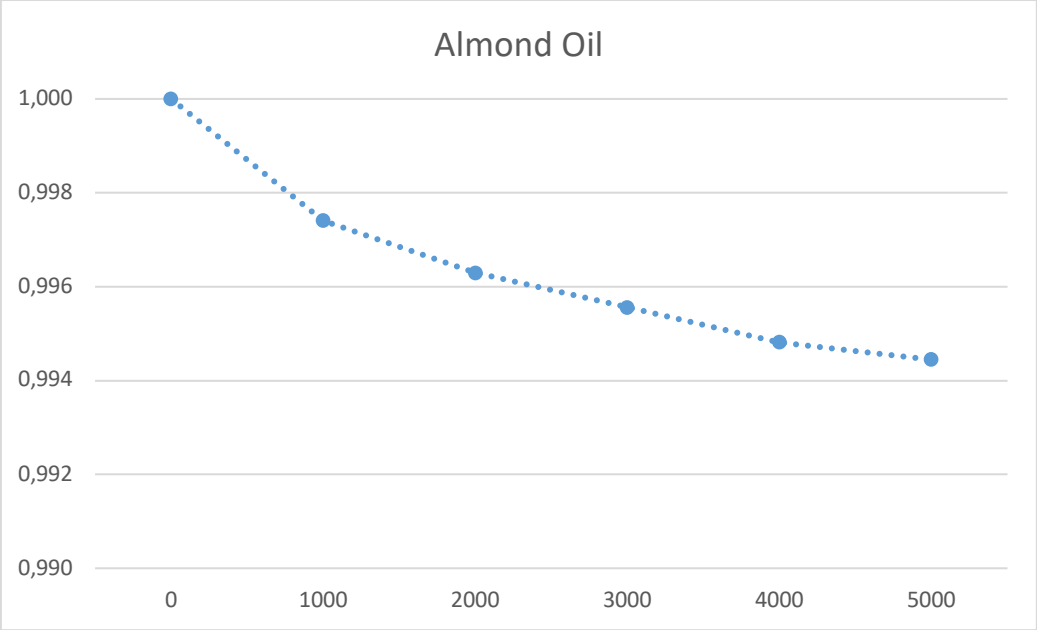


Figure 3-43: Survival probability curve for almond oil treated virgin hair after 5000 grooming cycles

Table 3-72: Survival probability and breakage likelihood calculation for virgin hair treated with baobab oil after 5000 grooming cycles

Baobab Oil					
Brushing Stroke	Total Fibers in Swatch	Fibers Broken	Non-Broken	Survival Probability	Breakage Likelihood
0	2700	0	3000	1,000	0,00%
1000	2700	7	2693	0,997	0,26%
2000	2693	5	2688	0,996	0,44%
3000	2688	2	2686	0,995	0,52%
4000	2686	2	2684	0,994	0,59%
5000	2684	1	2683	0,994	0,63%

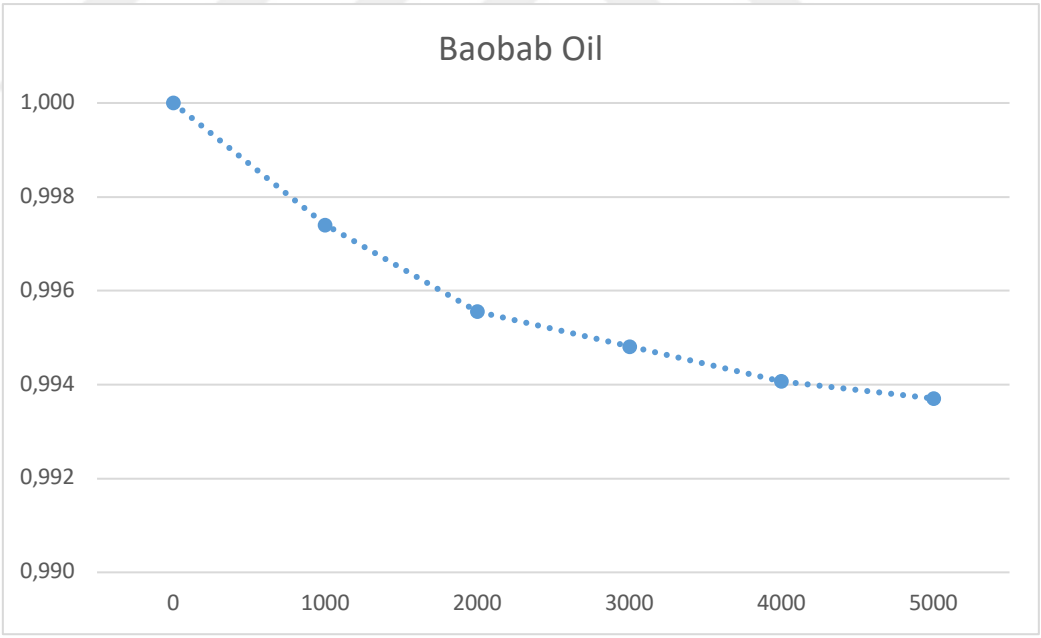


Figure 3-44: Survival probability curve for baobab oil treated virgin hair after 5000 grooming cycles

Table 3-73: Survival probability and breakage likelihood calculation for bleached once non-treated hair after 5000 grooming cycles

Baseline					
Brushing Stroke	Total Fibers in Swatch	Fibers Broken	Non-Broken	Survival Probability	Breakage Likelihood
0	2700	0	3000	1,000	0,00%
1000	2700	16	2684	0,994	0,59%
2000	2684	8	2676	0,991	0,89%
3000	2676	7	2669	0,989	1,15%
4000	2669	7	2662	0,986	1,41%
5000	2662	4	2658	0,984	1,56%

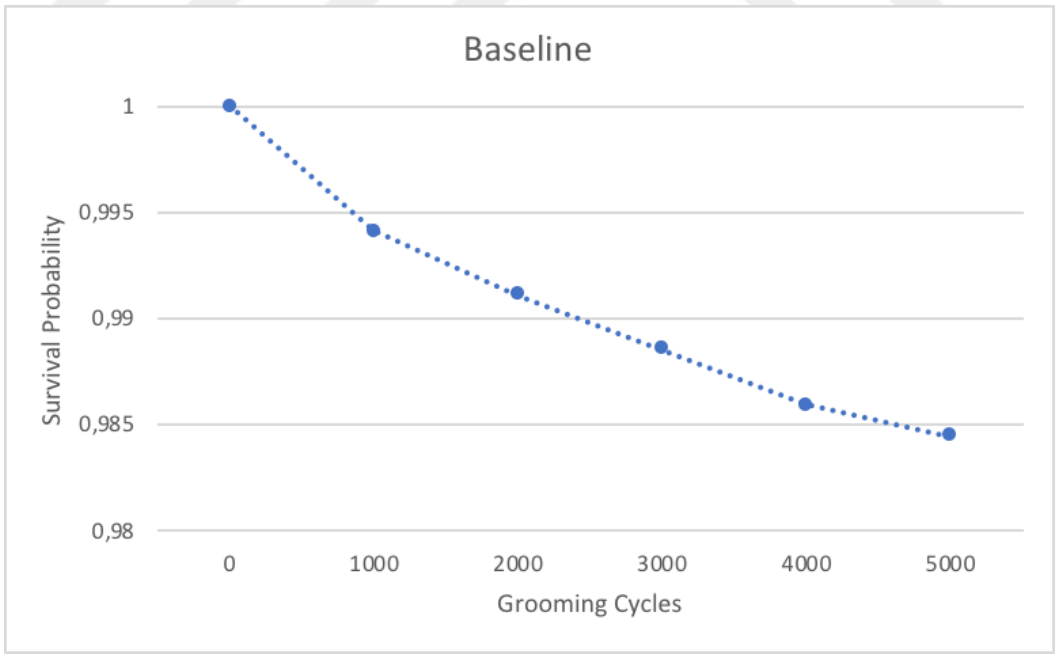


Figure 3-45: Survival probability curve for non-treated bleached once hair after 5000 grooming cycles

Table 3-74: Survival probability and breakage likelihood calculation for bleached once hair treated with mineral oil after 5000 grooming cycles

Mineral Oil					
Brushing Stroke	Total Fibers in Swatch	Fibers Broken	Non-Broken	Survival Probability	Breakage Likelihood
0	2700	0	3000	1,000	0,00%
1000	2700	12	2688	0,996	0,44%
2000	2688	6	2682	0,993	0,67%
3000	2682	3	2679	0,992	0,78%
4000	2679	3	2676	0,991	0,89%
5000	2676	2	2674	0,990	0,96%

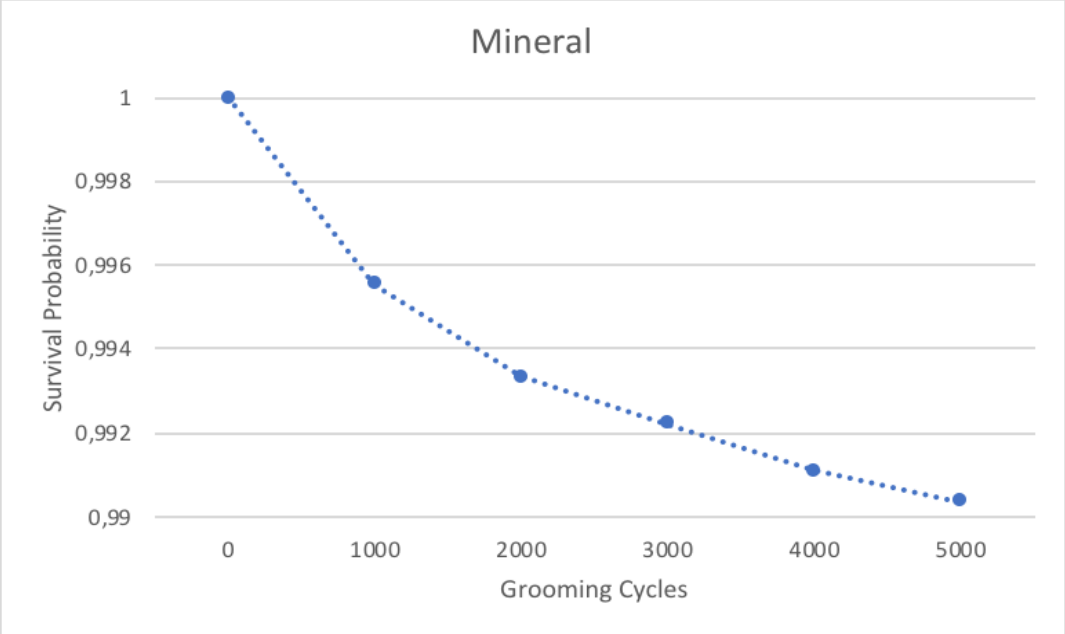


Figure 3-46: Survival probability curve for mineral oil treated bleached once hair after 5000 grooming cycles

Table 3-75: Survival probability and breakage likelihood calculation for bleached once hair treated with coconut oil after 5000 grooming cycles

Coconut Oil					
Brushing Stroke	Total Fibers in Swatch	Fibers Broken	Non-Broken	Survival Probability	Breakage Likelihood
0	2700	0	3000	1,000	0,00%
1000	2700	11	2689	0,996	0,41%
2000	2689	4	2685	0,994	0,56%
3000	2685	5	2680	0,993	0,74%
4000	2680	4	2676	0,991	0,89%
5000	2676	1	2675	0,991	0,93%

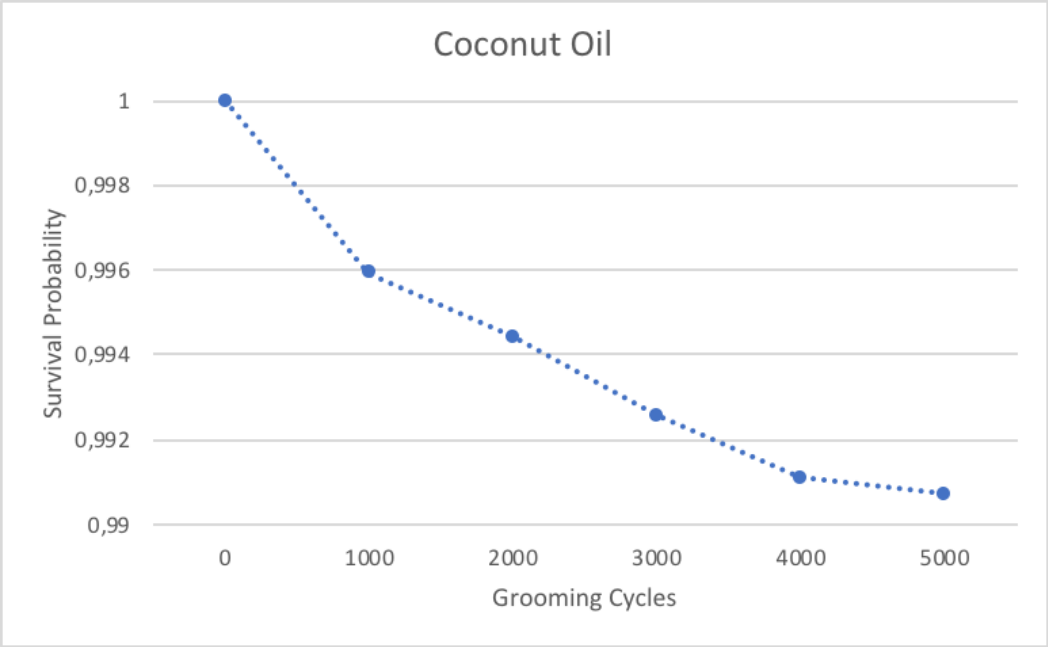


Figure 3-47: Survival probability curve for coconut oil treated linseed bleached once hair after 5000 grooming cycles

Table 3-76: Survival probability and breakage likelihood calculation for bleached once hair treated with linseed oil after 5000 grooming cycles

Linseed Oil					
Brushing Stroke	Total Fibers in Swatch	Fibers Broken	Non-Broken	Survival Probability	Breakage Likelihood
0	2700	0	3000	1,000	0,00%
1000	2700	12	2688	0,996	0,44%
2000	2688	5	2683	0,994	0,63%
3000	2683	4	2679	0,992	0,78%
4000	2679	4	2675	0,991	0,93%
5000	2675	1	2674	0,990	0,96%

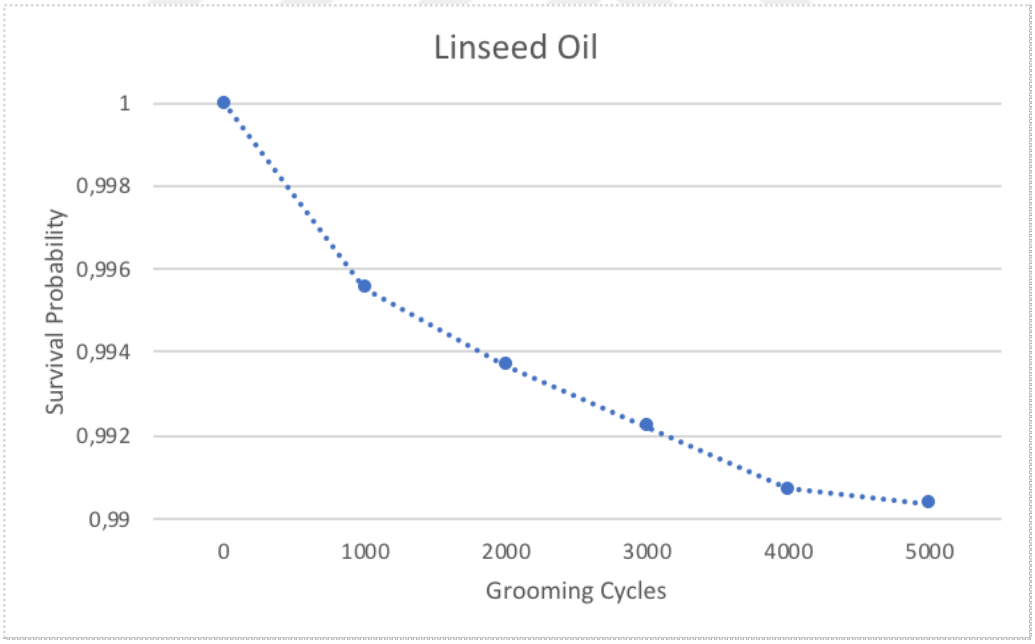


Figure 3-48: Survival probability curve for oil treated bleached once hair after 5000 grooming cycles

Table 3-77: Survival probability and breakage likelihood calculation for bleached once hair treated with almond oil after 5000 grooming cycles

Almond Oil					
Brushing Stroke	Total Fibers in Swatch	Fibers Broken	Non-Broken	Survival Probability	Breakage Likelihood
0	2700	0	3000	1,000	0,00%
1000	2700	10	2690	0,996	0,37%
2000	2690	6	2684	0,994	0,59%
3000	2684	3	2681	0,993	0,70%
4000	2681	1	2680	0,993	0,74%
5000	2680	1	2679	0,992	0,78%

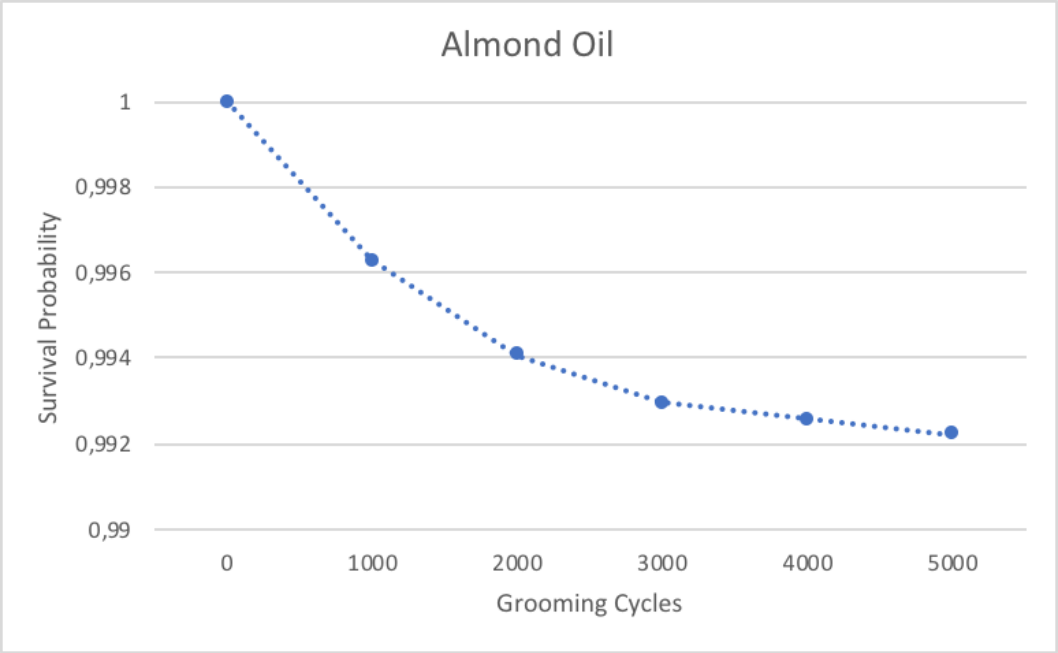


Figure 3-49: Survival probability curve for almond oil treated bleached once hair after 5000 grooming cycles

Table 3-78: Survival probability and breakage likelihood calculation for bleached once hair treated with baobab oil after 5000 grooming cycles

Baobab Oil					
Brushing Stroke	Total Fibers in Swatch	Fibers Broken	Non-Broken	Survival Probability	Breakage Likelihood
0	2700	0	3000	1,000	0,00%
1000	2700	11	2689	0,996	0,41%
2000	2689	5	2684	0,994	0,59%
3000	2684	5	2679	0,992	0,78%
4000	2679	3	2676	0,991	0,89%
5000	2676	1	2675	0,991	0,93%

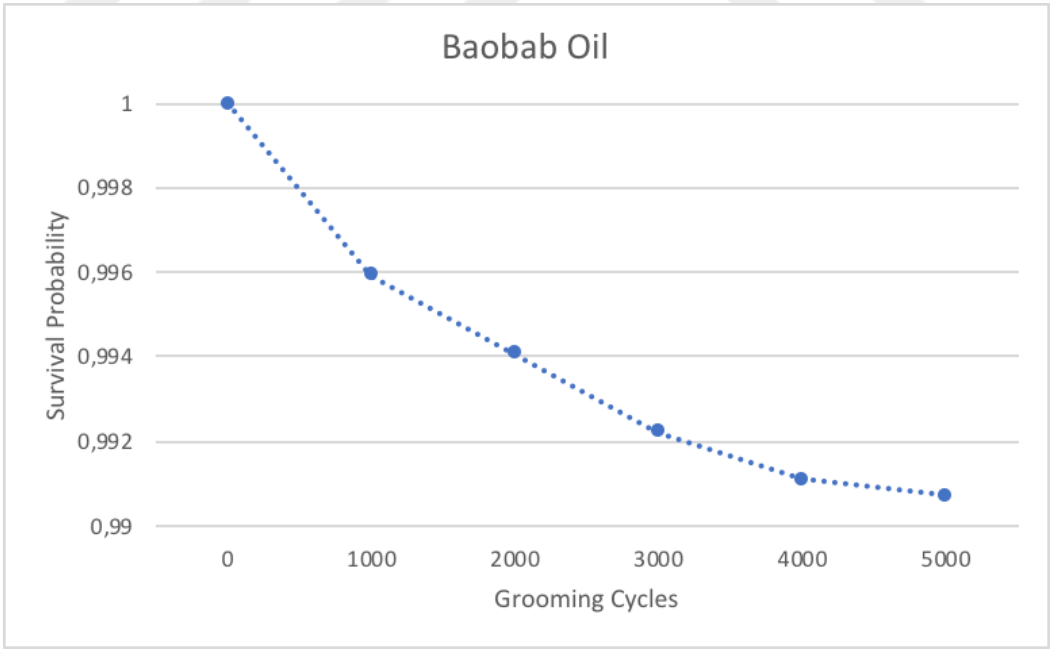


Figure 3-50: Survival probability curve for baobab oil treated bleached once hair after 5000 grooming

Table 3-79: Survival probability and breakage likelihood calculation for bleached once hair treated with baobab oil after 5000 grooming cycles

Baseline					
Brushing Stroke	Total Fibers in Swatch	Fibers Broken	Non-Broken	Survival Probability	Breakage Likelihood
0	2700	0	3000	1,000	0,00%
1000	2700	20	2680	0,993	0,74%
2000	2680	13	2667	0,988	1,22%
3000	2667	9	2658	0,984	1,56%
4000	2658	5	2653	0,983	1,74%
5000	2653	4	2649	0,981	1,89%

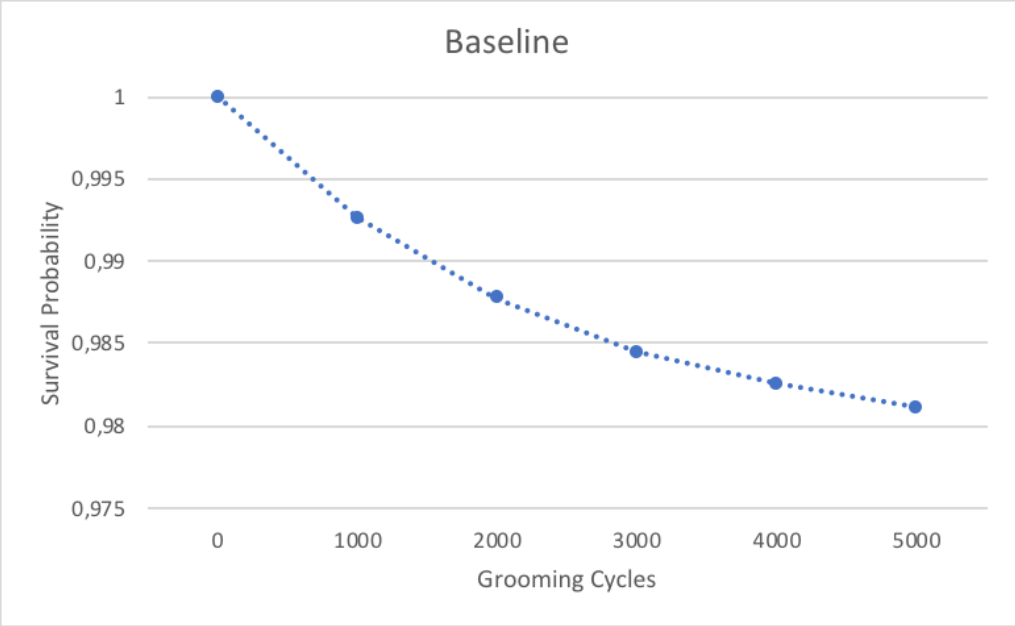


Figure 3-51: Survival probability curve for non-treated bleached x4 hair after 5000 grooming cycles

Table 3-80: Survival probability and breakage likelihood calculation for bleached x4 hair treated with mineral oil after 5000 grooming cycles

Mineral Oil					
Brushing Stroke	Total Fibers in Swatch	Fibers Broken	Non-Broken	Survival Probability	Breakage Likelihood
0	2700	0	3000	1,000	0,00%
1000	2700	14	2686	0,995	0,52%
2000	2686	8	2678	0,992	0,81%
3000	2678	7	2671	0,989	1,07%
4000	2671	4	2667	0,988	1,22%
5000	2667	2	2665	0,987	1,30%

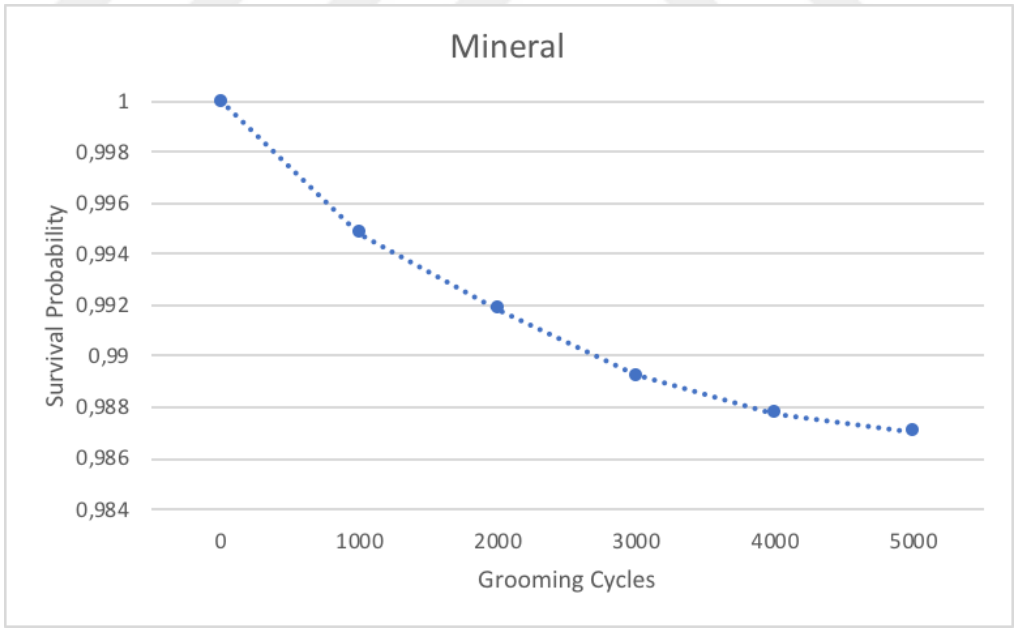


Figure 3-52: Survival probability curve for mineral oil treated bleached x4 hair after 5000 grooming

Table 3-81: Survival probability and breakage likelihood calculation for bleached x4 hair treated with coconut oil after 5000 grooming cycles

Coconut Oil					
Brushing Stroke	Total Fibers in Swatch	Fibers Broken	Non-Broken	Survival Probability	Breakage Likelihood
0	2700	0	3000	1,000	0,00%
1000	2700	13	2687	0,995	0,48%
2000	2687	8	2679	0,992	0,78%
3000	2679	5	2674	0,990	0,96%
4000	2674	4	2670	0,989	1,11%
5000	2670	3	2667	0,988	1,22%

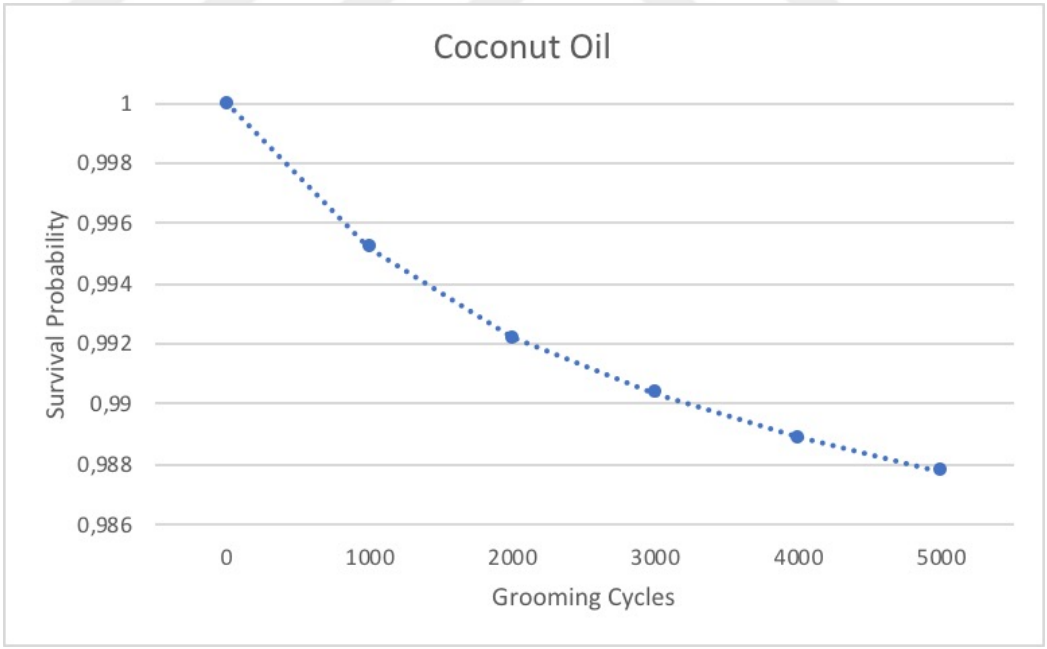


Figure 3-53: Survival probability curve for coconut oil treated bleached x4 hair after 5000 grooming cycles

Table 3-82: Survival probability and breakage likelihood calculation for bleached x4 hair treated with linseed oil after 5000 grooming cycles

Linseed Oil					
Brushing Stroke	Total Fibers in Swatch	Fibers Broken	Non-Broken	Survival Probability	Breakage Likelihood
0	2700	0	3000	1,000	0,00%
1000	2700	13	2687	0,995	0,48%
2000	2687	9	2678	0,992	0,81%
3000	2678	5	2673	0,990	1,00%
4000	2673	5	2668	0,988	1,19%
5000	2668	2	2666	0,987	1,26%

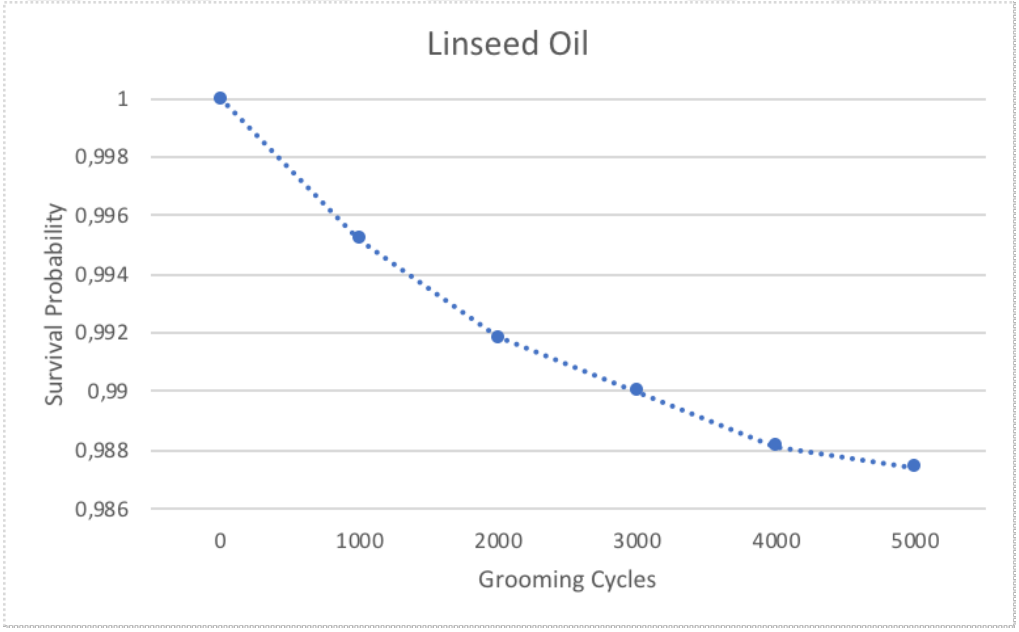


Figure 3-54: Survival probability curve for linseed oil treated bleached x4 hair after 5000 grooming

Table 3-83: Survival probability and breakage likelihood calculation for bleached x4 hair treated with almond oil after 5000 grooming cycles

Almond Oil					
Brushing Stroke	Total Fibers in Swatch	Fibers Broken	Non-Broken	Survival Probability	Breakage Likelihood
0	2700	0	3000	1,000	0,00%
1000	2700	11	2689	0,996	0,41%
2000	2689	8	2681	0,993	0,70%
3000	2681	5	2676	0,991	0,89%
4000	2676	5	2671	0,989	1,07%
5000	2671	2	2669	0,989	1,15%

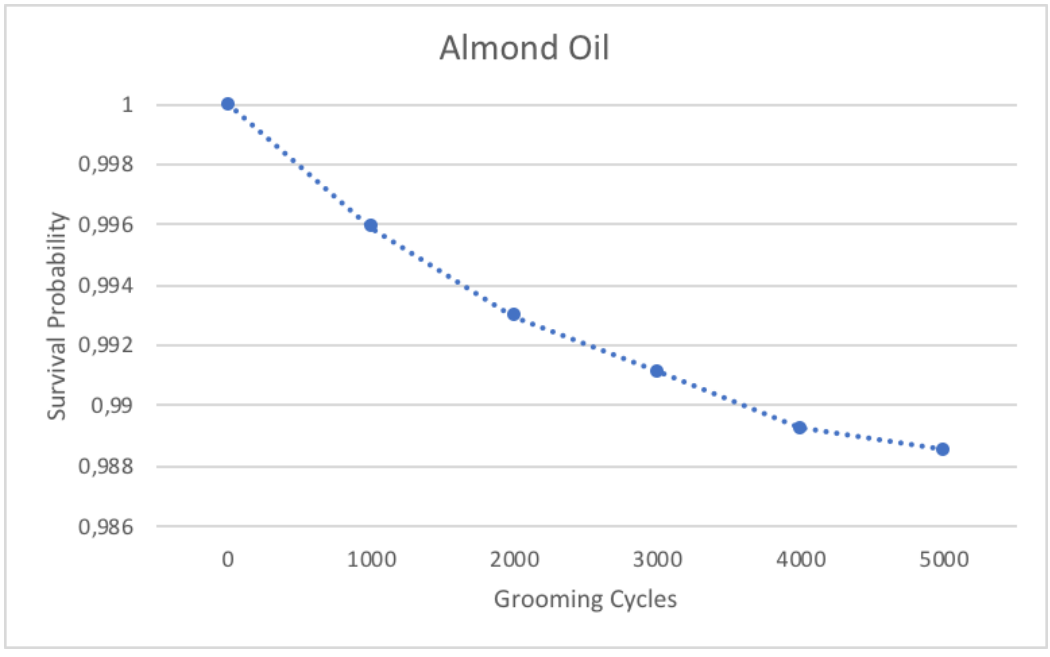


Figure 3-55: Survival probability curve for almond oil treated bleached x4 hair after 5000 grooming cycles

Table 3-84: Survival probability and breakage likelihood calculation for bleached x4 hair treated with baobab oil after 5000 grooming cycles

Baobab Oil					
Brushing Stroke	Total Fibers in Swatch	Fibers Broken	Non-Broken	Survival Probability	Breakage Likelihood
0	2700	0	3000	1,000	0,00%
1000	2700	12	2688	0,996	0,44%
2000	2688	8	2680	0,993	0,74%
3000	2680	5	2675	0,991	0,93%
4000	2675	5	2670	0,989	1,11%
5000	2670	2	2668	0,988	1,19%

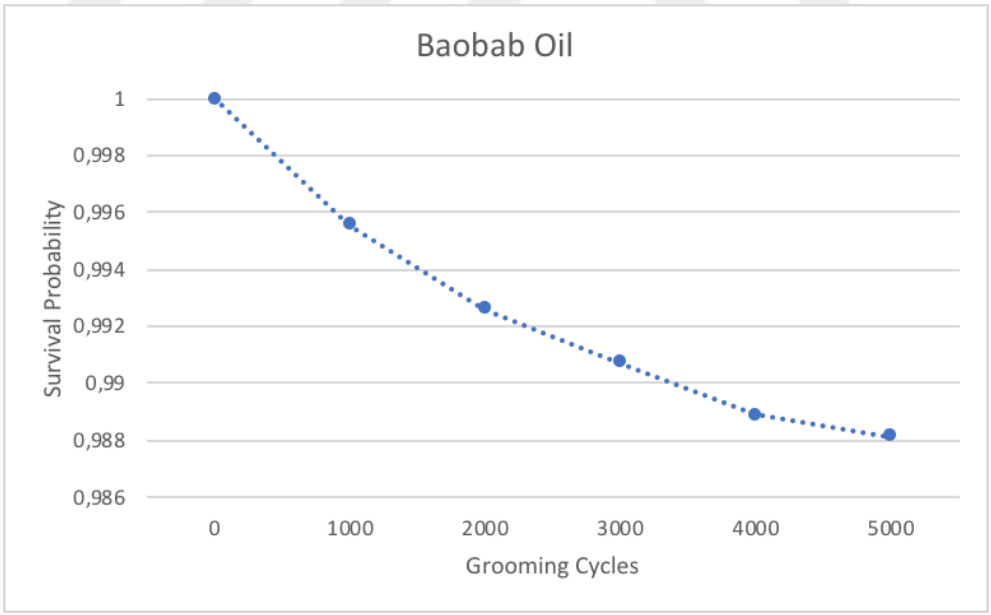


Figure 3-56: Survival probability curve for baobab oil treated bleached x4 hair after 5000 grooming

Table 3-85: Survival probability and breakage likelihood calculation for bleached x7 non-treated hair after 5000 grooming cycles

Baseline					
Brushing Stroke	Total Fibers in Swatch	Fibers Broken	Non-Broken	Survival Probability	Breakage Likelihood
0	2700	0	3000	1,000	0,00%
1000	2700	23	2677	0,991	0,85%
2000	2677	14	2663	0,986	1,37%
3000	2663	8	2655	0,983	1,67%
4000	2655	6	2649	0,981	1,89%
5000	2649	3	2646	0,980	2,00%

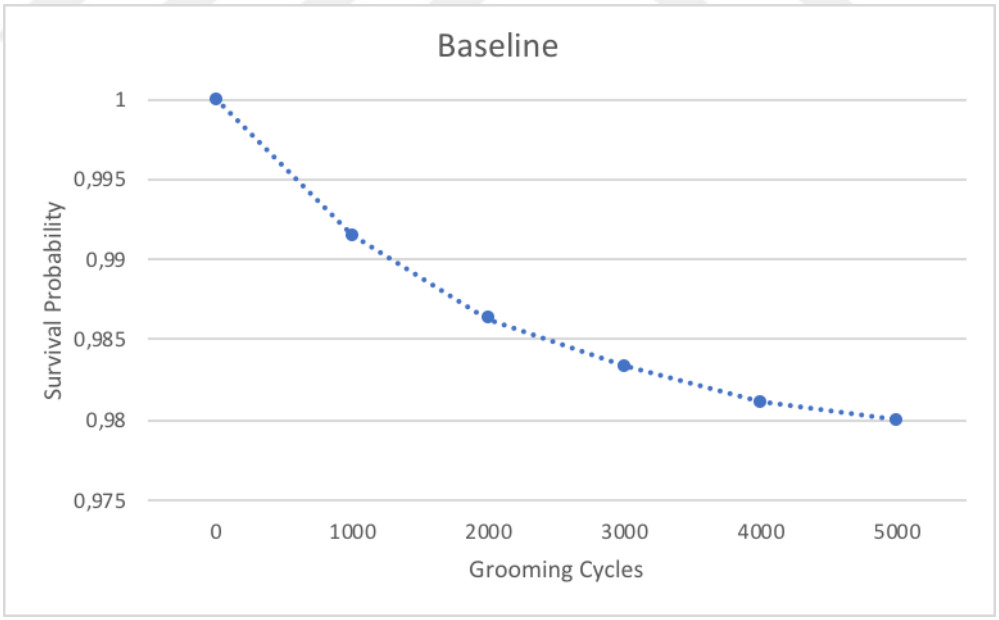


Figure 3-57: Survival probability curve for non-treated bleached x7 hair after 5000 grooming cycles

Table 3-86: Survival probability and breakage likelihood calculation for bleached x7 hair treated with mineral oil after 5000 grooming cycles

Mineral Oil					
Brushing Stroke	Total Fibers in Swatch	Fibers Broken	Non-Broken	Survival Probability	Breakage Likelihood
0	2700	0	3000	1,000	0,00%
1000	2700	15	2685	0,994	0,56%
2000	2685	11	2674	0,990	0,96%
3000	2674	5	2669	0,989	1,15%
4000	2669	4	2665	0,987	1,30%
5000	2665	3	2662	0,986	1,41%

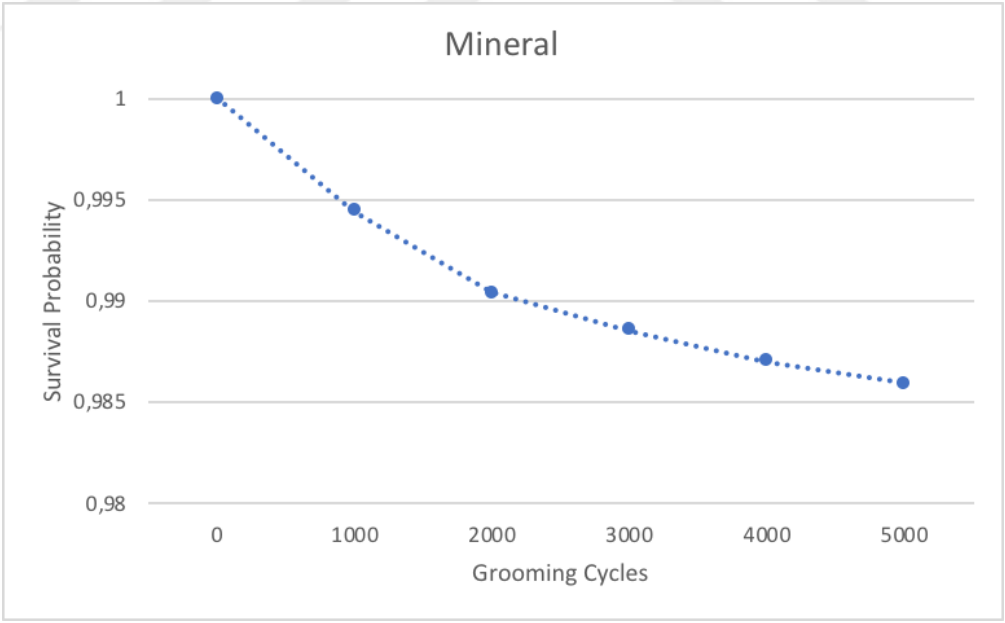


Figure 3-58: Survival probability curve for mineral oil treated bleached x7 hair after 5000 grooming cycles

Table 3-87: Survival probability and breakage likelihood calculation for bleached x7 hair treated with coconut oil after 5000 grooming cycles

Coconut Oil					
Brushing Stroke	Total Fibers in Swatch	Fibers Broken	Non-Broken	Survival Probability	Breakage Likelihood
0	2700	0	3000	1,000	0,00%
1000	2700	13	2687	0,995	0,48%
2000	2687	10	2677	0,991	0,85%
3000	2677	5	2672	0,990	1,04%
4000	2672	3	2669	0,989	1,15%
5000	2669	3	2666	0,987	1,26%

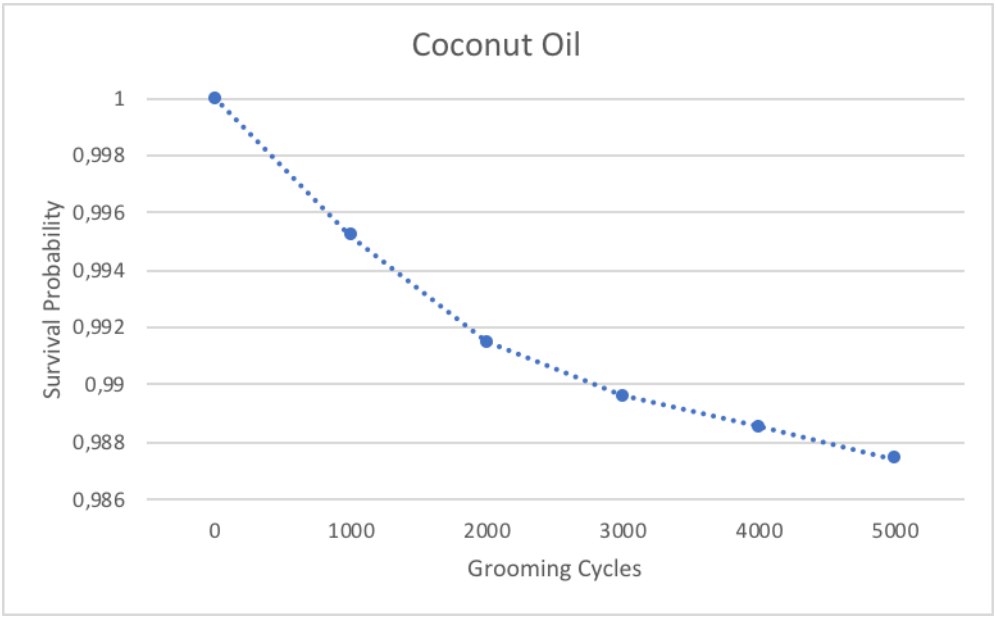


Figure 3-59: Survival probability curve for coconut oil treated bleached x7 hair after 5000 grooming cycles

Table 3-88: Survival probability and breakage likelihood calculation for bleached x7 hair treated with linseed oil after 5000 grooming cycles

Linseed Oil					
Brushing Stroke	Total Fibers in Swatch	Fibers Broken	Non-Broken	Survival Probability	Breakage Likelihood
0	2700	0	3000	1,000	0,00%
1000	2700	14	2686	0,995	0,52%
2000	2686	9	2677	0,991	0,85%
3000	2677	6	2671	0,989	1,07%
4000	2671	4	2667	0,988	1,22%
5000	2667	3	2664	0,987	1,33%

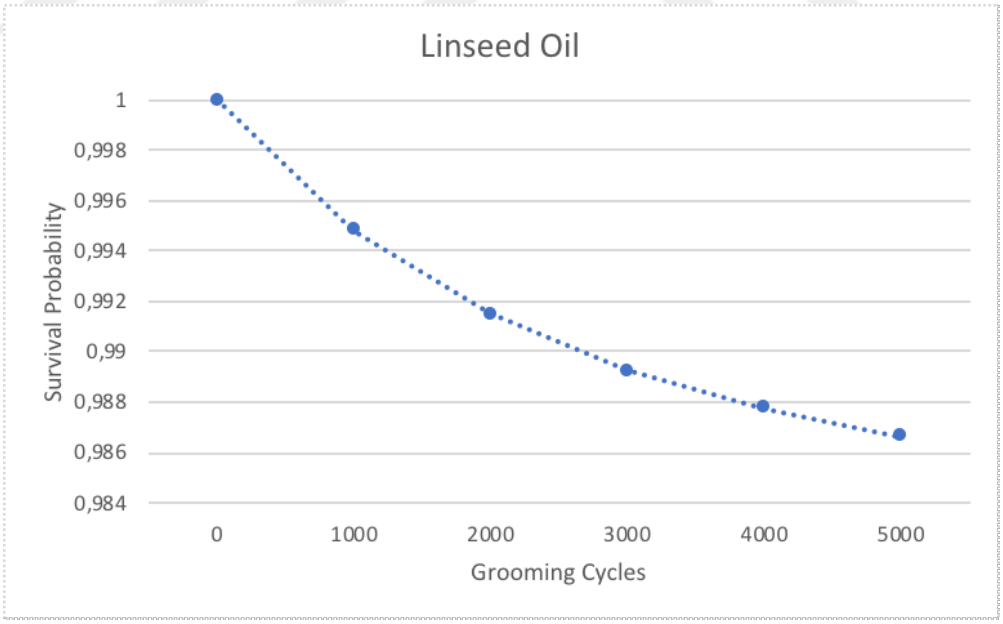


Figure 3-60: Survival probability curve for linseed oil treated bleached x7 hair after 5000 grooming

Table 3-89: Survival probability and breakage likelihood calculation for bleached x7 hair treated with almond oil after 5000 grooming cycles

Almond Oil					
Brushing Stroke	Total Fibers in Swatch	Fibers Broken	Non-Broken	Survival Probability	Breakage Likelihood
0	2700	0	3000	1,000	0,00%
1000	2700	13	2687	0,995	0,48%
2000	2687	8	2679	0,992	0,78%
3000	2679	7	2672	0,990	1,04%
4000	2672	4	2668	0,988	1,19%
5000	2668	2	2666	0,987	1,26%

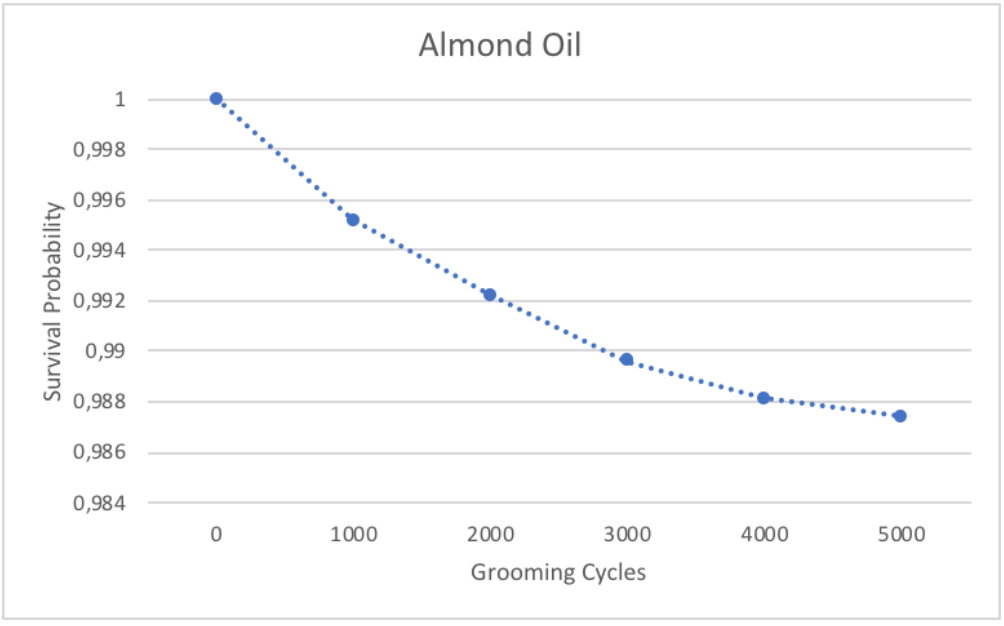


Figure 3-61: Survival probability curve for almond oil treated bleached x7 hair after 5000 grooming cycles

Table 3-90: Survival probability and breakage likelihood calculation for bleached x7 hair treated with baobab oil after 5000 grooming cycles

Baobab Oil					
Brushing Stroke	Total Fibers in Swatch	Fibers Broken	Non-Broken	Survival Probability	Breakage Likelihood
0	2700	0	3000	1,000	0,00%
1000	2700	13	2687	0,995	0,48%
2000	2687	9	2678	0,992	0,81%
3000	2678	6	2672	0,990	1,04%
4000	2672	4	2668	0,988	1,19%
5000	2668	3	2665	0,987	1,30%

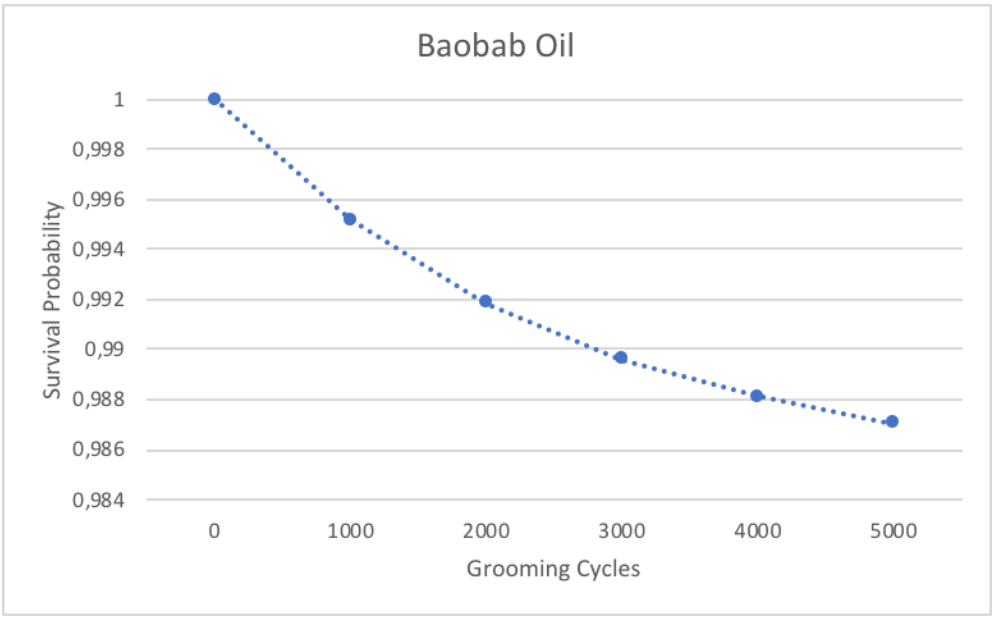


Figure 3-62: Survival probability curve for baobab oil treated bleached x7 hair after 5000 grooming cycles

3.5 POROSITY STATISTICAL ANALYSIS

Table 3-91: Statistical analysis data of weight loss of studied hair

	Group	Percentage of weight loss (m ± SD)	P Value
Baseline	Virgin	7,106 ± 0,294	.019
	Bleached 1	6,417 ± 0,187	
	Bleached 4	7,815 ± 0,214	
	Bleached 7	8,166 ± 0,230	
Mineral	Virgin	7,217 ± 0,351	.023
	Bleached 1	6,399 ± 0,447	
	Bleached 4	7,716 ± 0,352	
	Bleached 7	8,403 ± 0,315	
Coconut	Virgin	4,131 ± 0,287	.019
	Bleached 1	5,895 ± 0,302	
	Bleached 4	4,659 ± 0,162	
	Bleached 7	6,338 ± 0,168	
Linseed	Virgin	4,400 ± 0,264	.016
	Bleached 1	5,953 ± 0,158	
	Bleached 4	5,485 ± 0,291	
	Bleached 7	6,288 ± 0,197	
Almond	Virgin	3,979 ± 0,220	.038
	Bleached 1	5,095 ± 0,227	
	Bleached 4	5,249 ± 0,194	
	Bleached 7	4,810 ± 0,273	
Baobab	Virgin	4,585 ± 0,301	.022
	Bleached 1	5,663 ± 0,234	
	Bleached 4	6,592 ± 0,349	
	Bleached 7	6,237 ± 0,225	

When compared according to the type of applied oils, means of all of the previous samples are statistically different from each other ($P<0.05$).

Table 3-92: Statistical analysis data of weight loss of studied hair

	Group	Percentage of weight loss (m ± SD)	P Value
Virgin	Baseline	7,106 ± 0,294	.016
	Mineral	7,217 ± 0,351	
	Coconut	4,131 ± 0,287	
	Linseed	4,400 ± 0,264	
	Almond	3,979 ± 0,220	
	Baobab	4,585 ± 0,301	
Bleached 1	Baseline	6,417 ± 0,187	.022
	Mineral	6,399 ± 0,447	
	Coconut	5,895 ± 0,302	
	Linseed	5,953 ± 0,158	
	Almond	5,095 ± 0,227	
	Baobab	5,663 ± 0,234	
Bleached 4	Baseline	7,815 ± 0,214	.007
	Mineral	7,716 ± 0,352	
	Coconut	4,659 ± 0,162	
	Linseed	5,485 ± 0,291	
	Almond	5,249 ± 0,194	
	Baobab	6,592 ± 0,349	
Bleached 7	Baseline	8,166 ± 0,230	.014
	Mineral	8,403 ± 0,315	
	Coconut	6,338 ± 0,168	
	Linseed	6,288 ± 0,197	
	Almond	4,810 ± 0,273	
	Baobab	6,237 ± 0,225	

When compared according to the type of hair treatment, means of all of the previous samples are statistically different from each other ($P<0.05$).

Table 3-93: Statistical analysis data of weight loss of virgin and bleached 1 baseline

	Group	Percentage of weight loss (m ± SD)	P Value
Baseline	Virgin	7,106 ± 0,294	0.050
	Bleached 1	6,417 ± 0,187	

Means of Baseline Virgin and Baseline Bleached 1 are statistically different from each other (P=0.05).

Table 3-94: Statistical analysis data of weight loss of virgin and bleached 4 baseline

	Group	Percentage of weight loss (m ± SD)	P Value
Baseline	Virgin	7,106 ± 0,294	0.050
	Bleached 4	7,815 ± 0,214	

Means of Baseline Virgin and Baseline Bleached 4 are statistically different from each other (P=0.05).

Table 3-95: Statistical analysis data of weight loss of virgin and bleached 7 baseline

	Group	Percentage of weight loss (m ± SD)	P Value
Baseline	Virgin	7,106 ± 0,294	0.050
	Bleached 7	8,166 ± 0,230	

Means of Baseline Virgin and Baseline Bleached 7 are statistically different from each other (P=0.05).

Table 3-96: Statistical analysis data of weight loss of virgin and bleached 1 mineral

	Group	Percentage of weight loss (m ± SD)	P Value
Mineral	Virgin	7,217 ± 0,351	0.050
	Bleached 1	6,399 ± 0,447	

Means of Mineral Virgin and Mineral Bleached 1 are statistically different from each other (P=0.05).

Table 3-97: Statistical analysis data of weight loss of virgin and bleached 4 mineral

	Group	Percentage of weight loss (m ± SD)	P Value
Mineral	Virgin	7,217 ± 0,351	0.127
	Bleached 4	7,716 ± 0,352	

Means of Mineral Virgin and Mineral Bleached 7 are statistically different from each other (P=0.05).

Table 3-98: Statistical analysis data of weight loss of virgin and bleached 1 coconut

	Group	Percentage of weight loss (m ± SD)	P Value
Coconut	Virgin	4,131 ± 0,287	0.050
	Bleached 1	5,895 ± 0,302	

Means of Coconut Virgin and Coconut Bleached 1 are statistically different from each other (P=0.05).

Table 3-99: Statistical analysis data of weight loss of virgin and bleached 4 coconut

	Group	Percentage of weight loss (m ± SD)	P Value
Coconut	Virgin	4,131 ± 0,287	0.050
	Bleached 4	4,659 ± 0,162	

Means of Coconut Virgin and Coconut Bleached 4 are statistically different from each other (P=0.05).

Table 3-100: Statistical analysis data of weight loss of virgin and bleached 7 coconut

	Group	Percentage of weight loss (m ± SD)	P Value
Coconut	Virgin	4,131 ± 0,287	0.050
	Bleached 7	6,338 ± 0,168	

Means of Coconut Virgin and Coconut Bleached 7 are statistically different from each other (P=0.05).

Table 3-101: Statistical analysis data of weight loss of virgin and bleached 1 linseed

	Group	Percentage of weight loss (m ± SD)	P Value
Linseed	Virgin	4,400 ± 0,264	0.050
	Bleached 1	5,953 ± 0,158	

Means of Linseed Virgin and Linseed Bleached 1 are statistically different from each other (P=0.05).

Table 3-102: Statistical analysis data of weight loss of virgin and bleached 4 linseed

	Group	Percentage of weight loss (m ± SD)	P Value
Linseed	Virgin	4,400 ± 0,264	0.050
	Bleached 4	5,485 ± 0,291	

Means of Linseed Virgin and Linseed Bleached 7 are statistically different from each other (P=0.05).

Table 3-103: Statistical analysis data of weight loss of virgin and bleached 1 almond

	Group	Percentage of weight loss (m ± SD)	P Value
Almond	Virgin	3,979 ± 0,220	0.050
	Bleached 1	5,095 ± 0,227	

Means of Almond Virgin and Almond Bleached 1 are statistically different from each other (P=0.05).

Table 3-104: Statistical analysis data of weight loss of virgin and bleached 4 almond

	Group	Percentage of weight loss (m ± SD)	P Value
Almond	Virgin	3,979 ± 0,220	0.050
	Bleached 4	5,249 ± 0,194	

Means of Almond Virgin and Almond Bleached 4 are statistically different from each other (P=0.05).

Table 3-105: Statistical analysis data of weight loss of virgin and bleached 7 almond

	Group	Percentage of weight loss (m ± SD)	P Value
Almond	Virgin	3,979 ± 0,220	0.050
	Bleached 7	4,810 ± 0,273	

Means of Almond Virgin and Almond Bleached 7 are statistically different from each other (P=0.05).

Table 3-106: Statistical analysis data of weight loss of virgin and bleached 1 baobab

	Group	Percentage of weight loss (m ± SD)	P Value
Baobab	Virgin	4,585 ± 0,301	0.050
	Bleached 1	5,663 ± 0,234	

Means of Baobab Virgin and Baobab Bleached 1 are statistically different from each other (P=0.05).

Table 3-107: Statistical analysis data of weight loss of virgin and bleached 4 baobab

	Group	Percentage of weight loss (m ± SD)	P Value
Baobab	Virgin	4,585 ± 0,301	0.050
	Bleached 4	6,592 ± 0,349	

Means of Baobab Virgin and Baobab Bleached 7 are statistically different from each other (P=0.05).

Table 3-108: Statistical analysis data of weight loss of virgin baseline and mineral

	Group	Percentage of weight loss (m ± SD)	P Value
Virgin	Baseline	7,106 ± 0,294	0.513
	Mineral	7,217 ± 0,351	

Means of Virgin Baseline and Virgin Mineral are not statistically different from each other (P>0.05).

Table 3-109: Statistical analysis data of weight loss of virgin baseline and coconut

	Group	Percentage of weight loss (m ± SD)	P Value
Virgin	Baseline	7,106 ± 0,294	0.050
	Coconut	4,131 ± 0,287	

Means of Virgin Baseline and Virgin Coconut are statistically different from each other (P=0.05).

Table 3-110: Statistical analysis data of weight loss of virgin baseline and linseed

	Group	Percentage of weight loss (m ± SD)	P Value
Virgin	Baseline	7,106 ± 0,294	0.050
	Linseed	4,400 ± 0,264	

Means of Virgin Baseline and Virgin Linseed are statistically different from each other (P=0.05).

Table 3-111: Statistical analysis data of weight loss of virgin baseline and almond

	Group	Percentage of weight loss (m ± SD)	P Value
Virgin	Baseline	7,106 ± 0,294	0.050
	Almond	3,979 ± 0,220	

Means of Virgin Baseline and Virgin Almond are statistically different from each other (P=0.05).

Table 3-112: Statistical analysis data of weight loss of virgin baseline and baobab

	Group	Percentage of weight loss (m ± SD)	P Value
Virgin	Baseline	7,106 ± 0,294	0.050
	Baobab	4,585 ± 0,301	

Means of Virgin Baseline and Virgin Baobab are statistically different from each other (P=0.05).

Table 3-113: Statistical analysis data of weight loss of bleached 1 baseline and mineral

	Group	Percentage of weight loss (m ± SD)	P Value
Bleached 1	Baseline	6,417 ± 0,187	0.827
	Mineral	6,399 ± 0,447	

Means of Bleached x1 Baseline and Bleached x1 Mineral are not statistically different from each other (P>0.05).

Table 3-114: Statistical analysis data of weight loss of bleached 1 baseline and coconut

	Group	Percentage of weight loss (m ± SD)	P Value
Bleached 1	Baseline	6,417 ± 0,187	0.050
	Coconut	5,895 ± 0,302	

Means of Bleached x1 Baseline and Bleached x1 Coconut are statistically different from each other (P=0.05).

Table 3-115: Statistical analysis data of weight loss of bleached 1 baseline and linseed

	Group	Percentage of weight loss (m ± SD)	P Value
Bleached 1	Baseline	6,417 ± 0,187	0.050
	Linseed	5,953 ± 0,158	

Means of Bleached x1 Baseline and Bleached x1 Linseed are statistically different from each other (P=0.05).

Table 3-116: Statistical analysis data of weight loss of bleached 1 baseline and almond

	Group	Percentage of weight loss (m ± SD)	P Value
Bleached 1	Baseline	6,417 ± 0,187	0.050
	Almond	5,095 ± 0,227	

Means of Bleached x1 Baseline and Bleached x1 Almond are statistically different from each other (P=0.05).

Table 3-117: Statistical analysis data of weight loss of bleached 1 baseline and baobab

	Group	Percentage of weight loss (m ± SD)	P Value
Bleached 1	Baseline	6,417 ± 0,187	0.050
	Baobab	5,663 ± 0,234	

Means of Bleached x1 Baseline and Bleached x1 Baobab are statistically different from each other (P=0.05).

Table 3-118: Statistical analysis data of weight loss of bleached 4 baseline and mineral

	Group	Percentage of weight loss (m ± SD)	P Value
Bleached 4	Baseline	7,815 ± 0,214	0.827
	Mineral	7,716 ± 0,352	

Means of Bleached x4 Baseline and Bleached x4 Mineral are not statistically different from each other (P>0.05).

Table 3-119: Statistical analysis data of weight loss of bleached 4 baseline and coconut

	Group	Percentage of weight loss (m ± SD)	P Value
Bleached 4	Baseline	7,815 ± 0,214	0.050
	Coconut	4,659 ± 0,162	

Means of Bleached x4 Baseline and Bleached x4 Coconut are statistically different from each other (P=0.05).

Table 3-120: Statistical analysis data of weight loss of bleached 4 baseline and linseed

	Group	Percentage of weight loss (m ± SD)	P Value
Bleached 4	Baseline	7,815 ± 0,214	0.050
	Linseed	5,485 ± 0,291	

Means of Bleached x4 Baseline and Bleached x4 Linseed are statistically different from each other (P=0.05).

Table 3-121: Statistical analysis data of weight loss of bleached 4 baseline and almond

	Group	Percentage of weight loss (m ± SD)	P Value
Bleached 4	Baseline	7,815 ± 0,214	0.050
	Almond	5,249 ± 0,194	

Means of Bleached x4 Baseline and Bleached x4 Almond are statistically different from each other (P=0.05).

Table 3-122: Statistical analysis data of weight loss of bleached 4 baseline and almond

	Group	Percentage of weight loss (m ± SD)	P Value
Bleached 4	Baseline	7,815 ± 0,214	0.050
	Baobab	6,592 ± 0,349	

Means of Bleached x4 Baseline and Bleached x4 Baobab are statistically different from each other (P=0.05).

Table 3-123: Statistical analysis data of weight loss of bleached 7 baseline and mineral

	Group	Percentage of weight loss (m ± SD)	P Value
Bleached 7	Baseline	8,166 ± 0,230	0.513
	Mineral	8,403 ± 0,315	

Means of Bleached x7 Baseline and Bleached x7 Mineral are not statistically different from each other (P>0.05).

Table 3-124: Statistical analysis data of weight loss of bleached 7 baseline and coconut

	Group	Percentage of weight loss (m ± SD)	P Value
Bleached 7	Baseline	8,166 ± 0,230	0.050
	Coconut	6,338 ± 0,168	

Means of Bleached x7 Baseline and Bleached x7 Coconut are statistically different from each other (P=0.05).

Table 3-125: Statistical analysis data of weight loss of bleached 7 baseline and linseed

	Group	Percentage of weight loss (m ± SD)	P Value
Bleached 7	Baseline	8,166 ± 0,230	0.050
	Linseed	6,288 ± 0,197	

Means of Bleached x7 Baseline and Bleached x7 Linseed are statistically different from each other (P=0.05).

Table 3-126: Statistical analysis data of weight loss of bleached 7 baseline and almond

	Group	Percentage of weight loss (m ± SD)	P Value
Bleached 7	Baseline	8,166 ± 0,230	0.050
	Almond	4,810 ± 0,273	

Means of Bleached x7 Baseline and Bleached x7 Almond are statistically different from each other (P=0.05).

Table 3-127: Statistical analysis data of weight loss of bleached 7 baseline and baobab

	Group	Percentage of weight loss (m ± SD)	P Value
Bleached 7	Baseline	8,166 ± 0,230	0.050
	Baobab	6,237 ± 0,225	

Means of Bleached x7 Baseline and Bleached x7 Baobab are statistically different from each other (P=0.05).

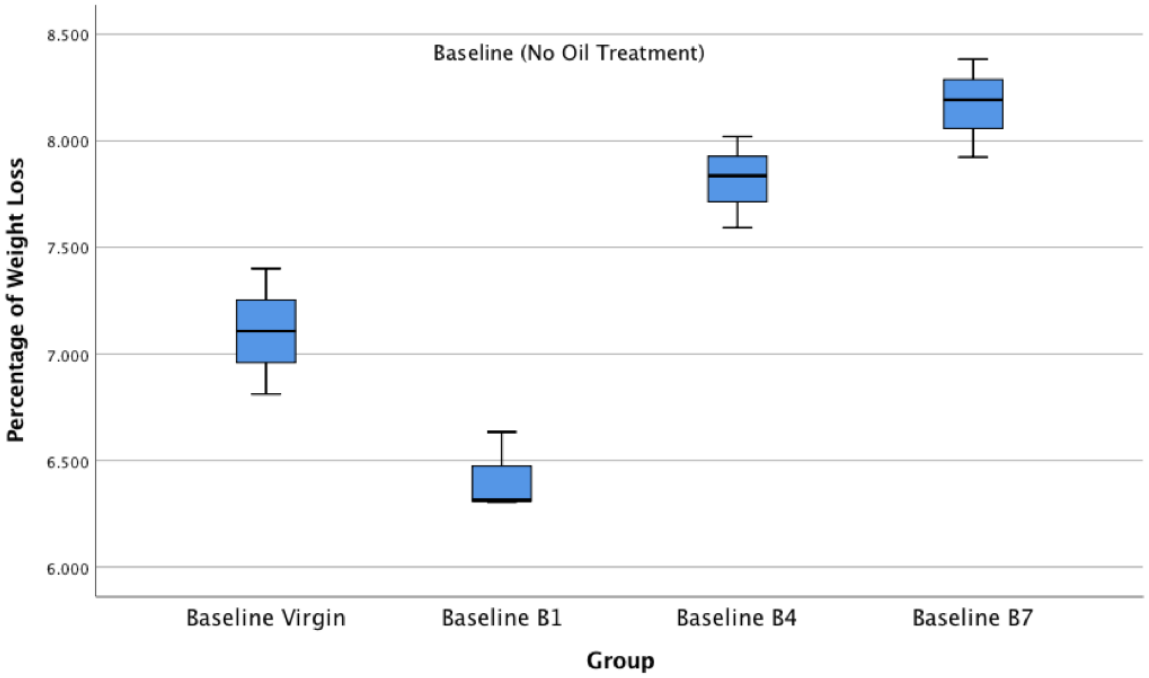


Figure 3-63: Boxplot representing % of weight loss for non-treated hair samples

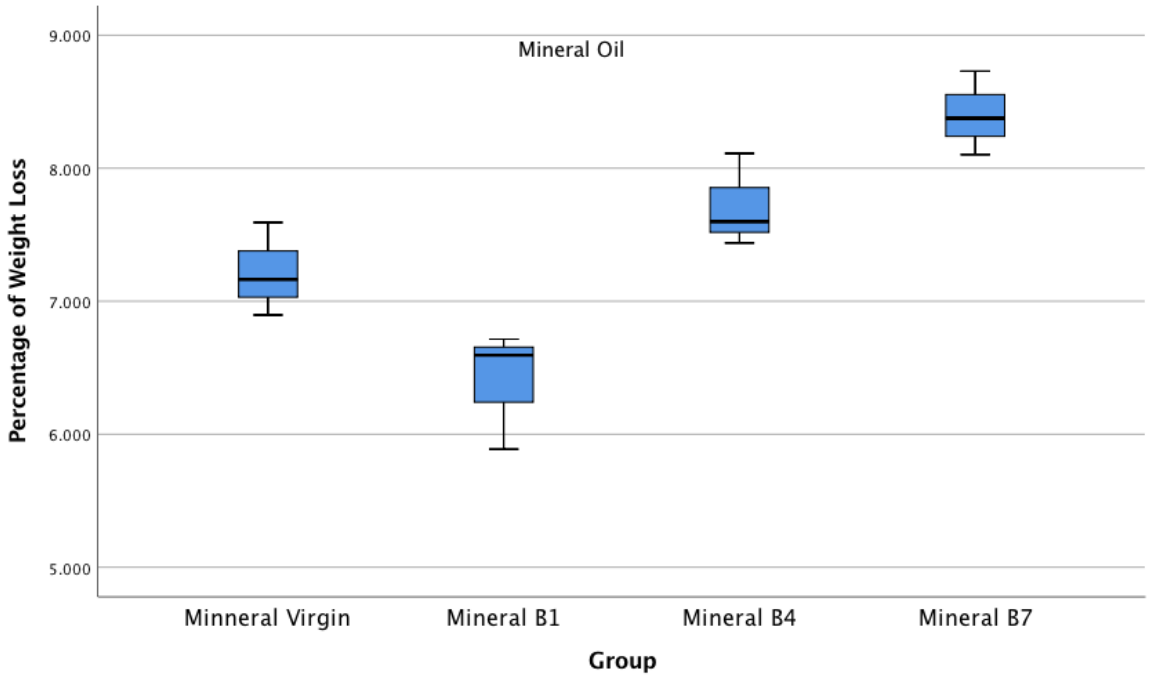


Figure 3-64: Boxplot representing % of weight loss for Mineral oil treated samples

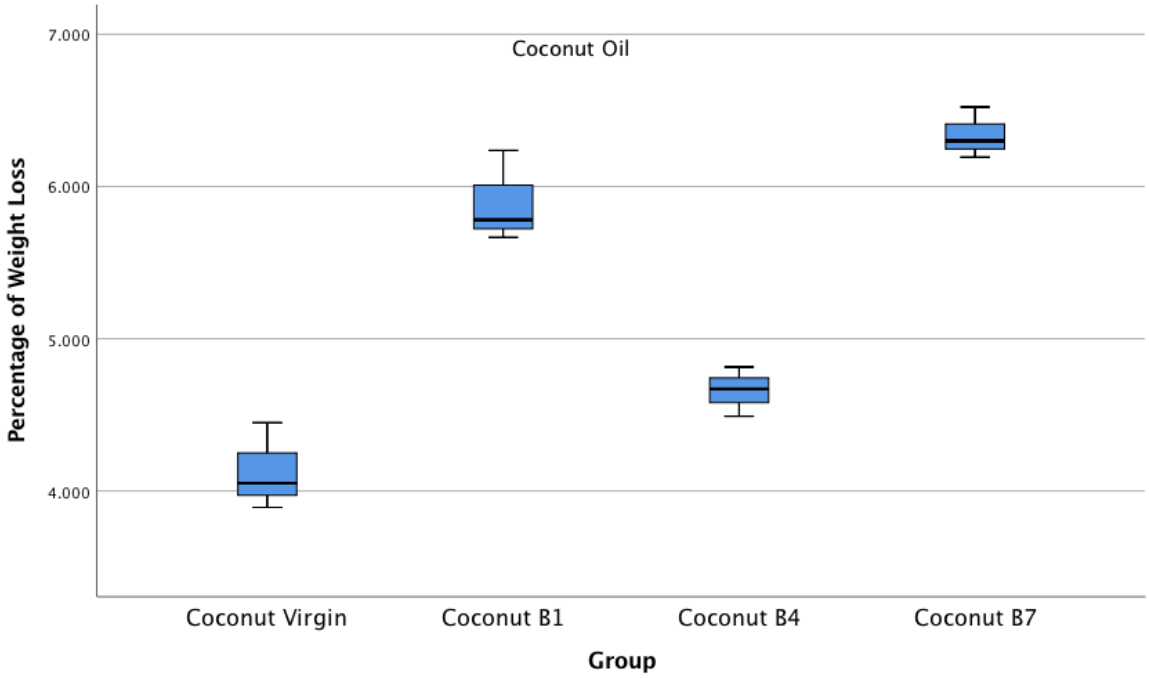


Figure 3-65: Boxplot representing % of weight loss for coconut oil treated samples

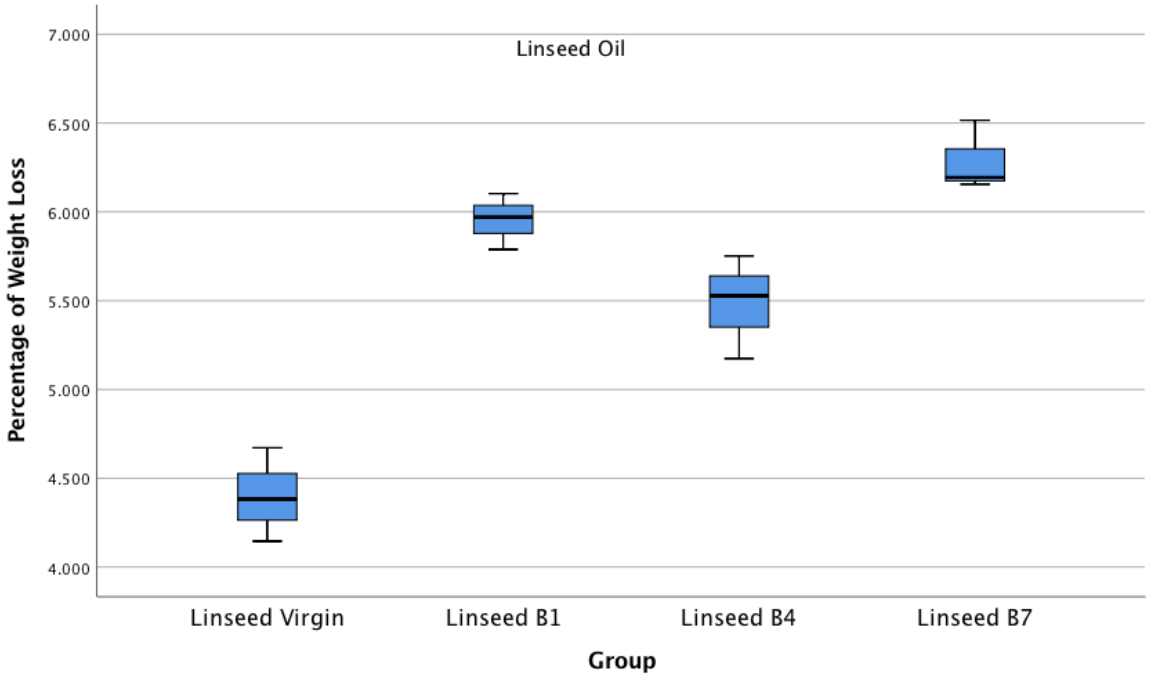


Figure 3-66: Boxplot representing % of weight loss for linseed oil treated samples

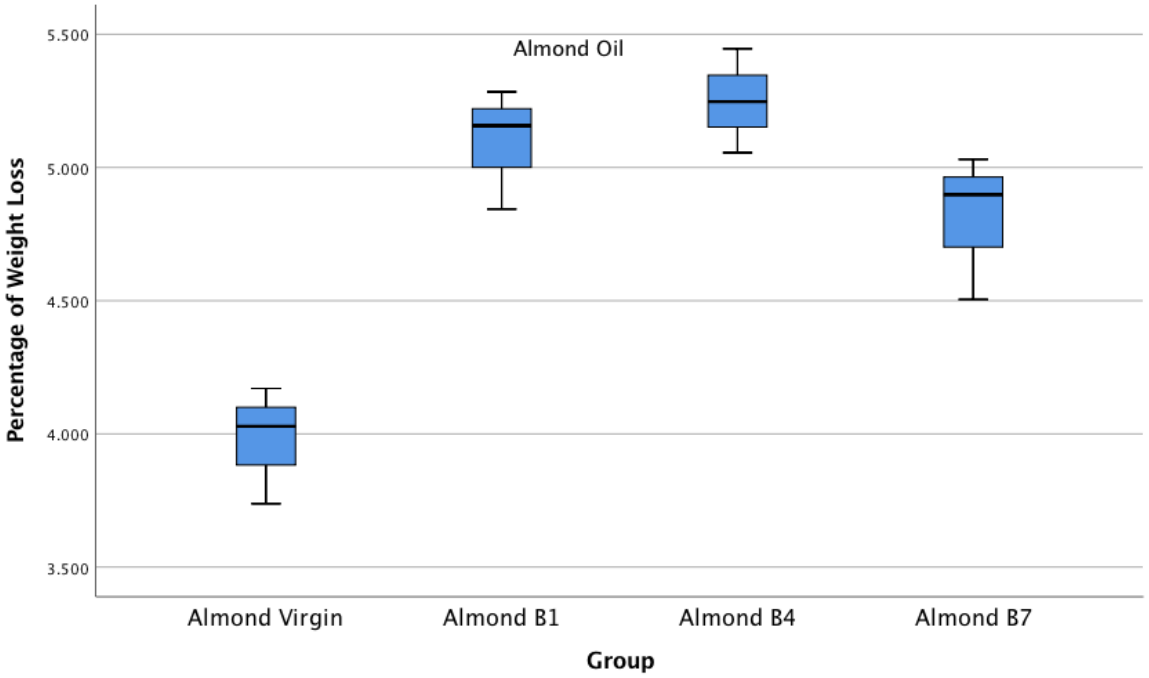


Figure 3-67: Boxplot representing % of weight loss for almond oil treated samples

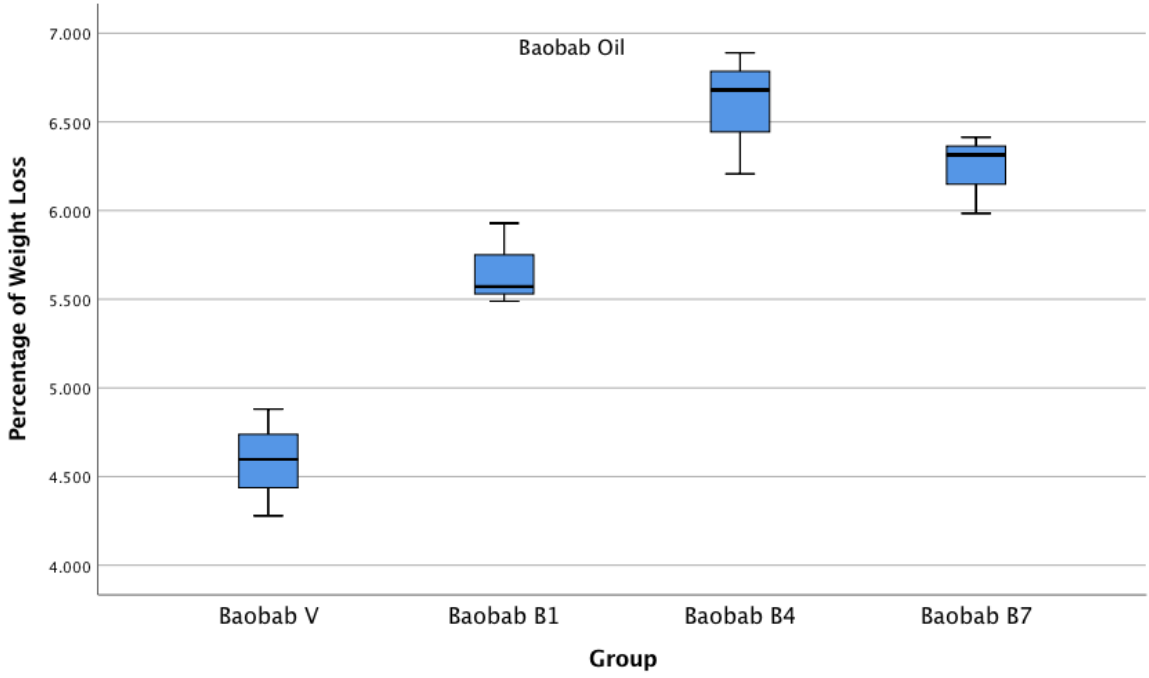


Figure 3-68: Boxplot representing % of weight loss for baobab oil treated samples

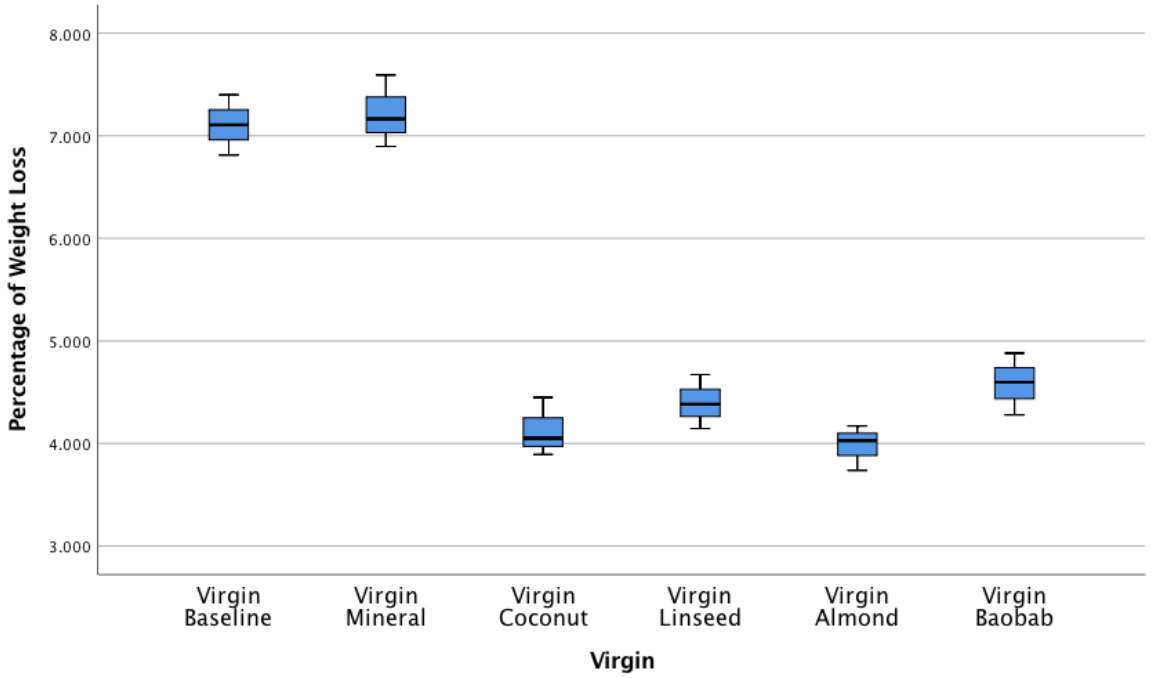


Figure 3-69: Boxplot representing % of weight loss for virgin hair treated with different oils

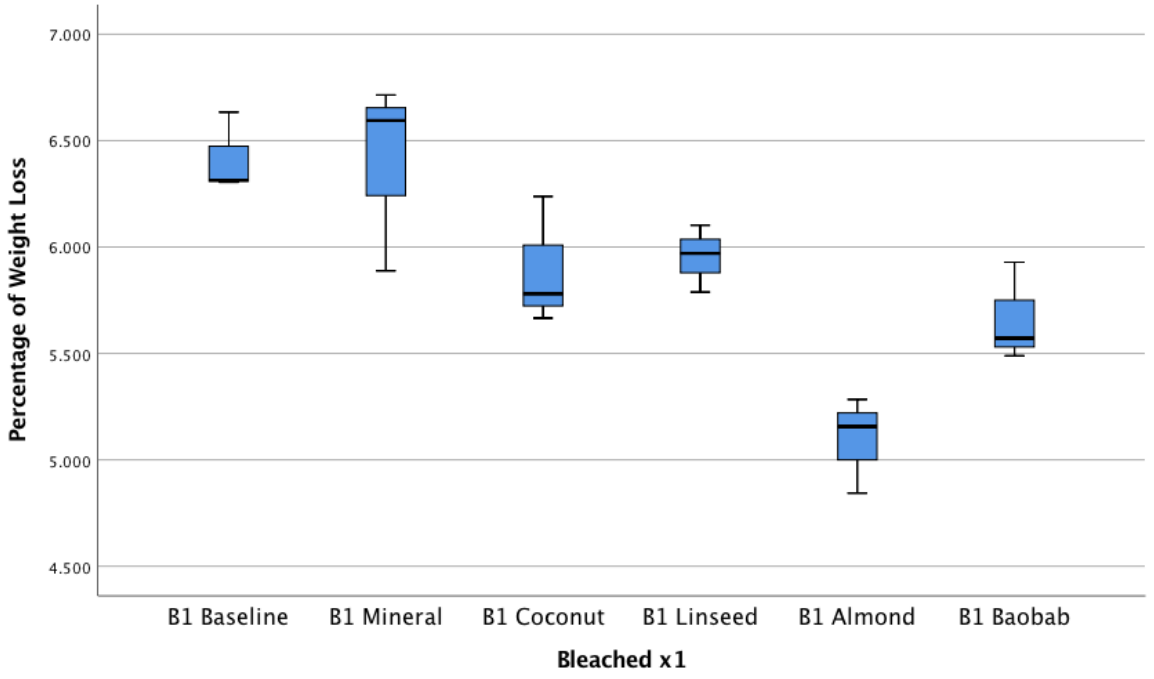


Figure 3-70: Boxplot representing % of weight loss for bleached once hair treated with different oils

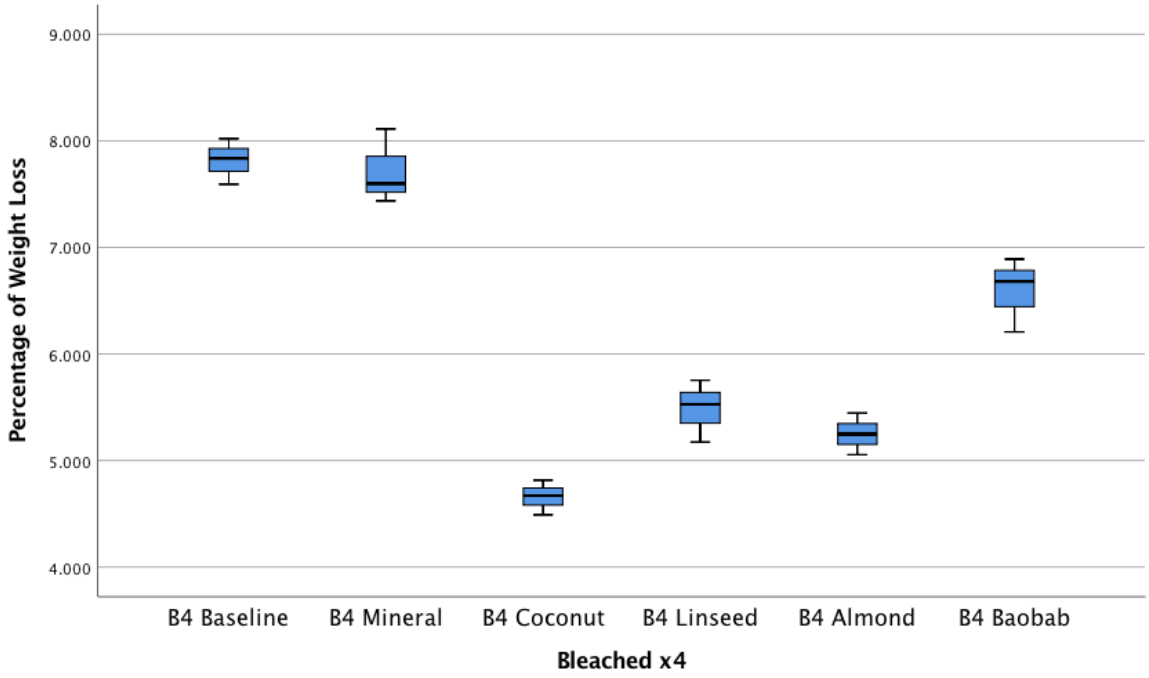


Figure 3-71: Boxplot representing % of weight loss for bleached x4 hair treated with different oils

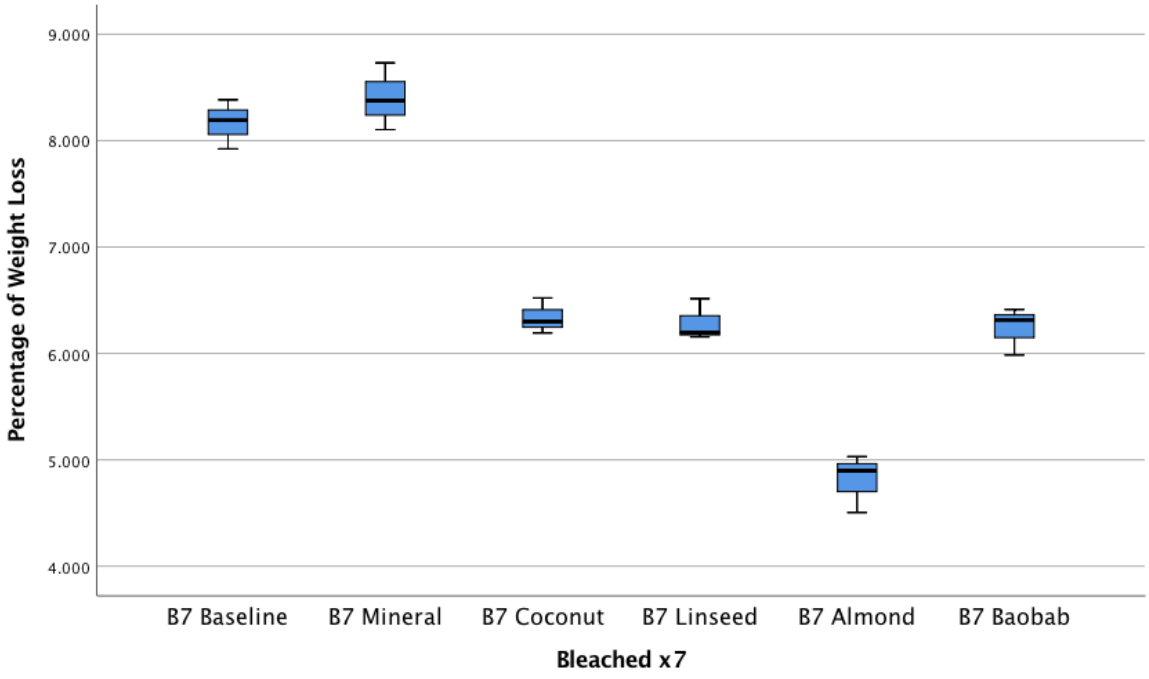


Figure 3-72: Boxplot representing % of weight loss for bleached x4 hair treated with different oils

3.6 DIFFERENTIAL SCANNING CALORIMETRY

Table 3-128: Open pans, dry pans, dry pans with holes DSC thermograms

Test Conditions	Temperature (C°)
VH 1 (Virgin hair), open pan	235,5
VH 2 (Virgin hair), open pan	235,8
VH 1 (Virgin hair), dry, closed pan	230,7 (121,2)
VH 2 (Virgin hair), dry, closed pan	232,8 (121,0)
BH1 (Bleached once) dry, closed pan with hole	251,6
BH2 (Bleached once) dry, closed pan with hole	251,4
VH Virgin hair +Boabab oil open pan	234,0
VH Virgin hair +Boabab oil open pan	235,1

Table 3-129: Dry pan, dry pan with holes, open pan thermograms, sample amount 5mg

Test Conditions	Peak Temperature (C°)	Enthalpy (mJ/mg)
VH (Virgin hair), dry, closed pan	221,00-222,00	1,55-1,94
VH (Virgin hair), dry, closed pan with holes	225,00-225,50	1,75-2,06
VH (Virgin hair), dry, open pan	225,30- 225,80	1,08-1,69
BH1 (Bleached once) dry, closed pan	229,7-231,6	1,83-1,99
BH1 (Bleached once) dry, closed pan with holes	231,1-232,60	1,50-1,81
BH1 (Bleached once) dry, open pan	232.00-232,30	1,18-1,43
BH7 (Bleached hair 7 times), dry, closed pan	246,3-245,3	1,66-1,95
BH7 (Bleached hair 7 times), dry, closed pan with holes	247,6-248,2	1,12-1,49
BH7 (Bleached hair 7 times) dry, open pan	247,4-248	1,1-1,18

Table 3-130: The Closed pressure pan thermograms, sample size 5 mg 50 µl water

Test Conditions	Peak Temperature (C°)	Enthalpy (mJ/mg) ±SD
VH (Virgin hair)	157.50±1.12	11.75±1.11
BH (1) (Bleached once)	154.65±1.41	11.50±0.02
BH (4) (Bleached 4 times)	150.20±0.06	11.25±0.02
BH (7) (Bleached 7 times)	141.90±1.01	10.85±0.01

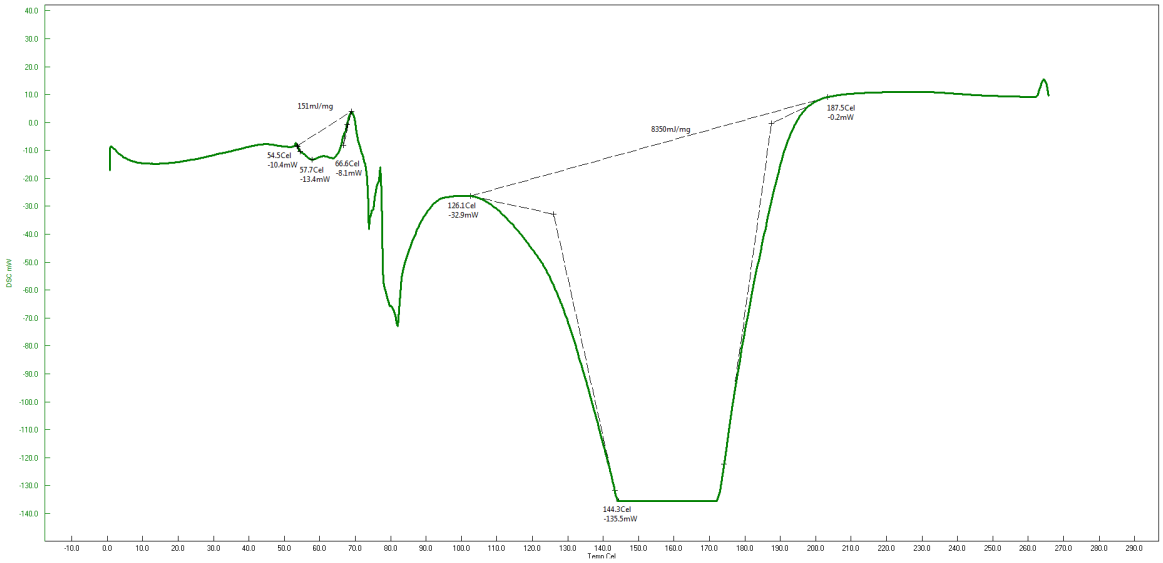


Figure 3-73: DSC Analysis spectra of virgin hair samples treated with mineral oil

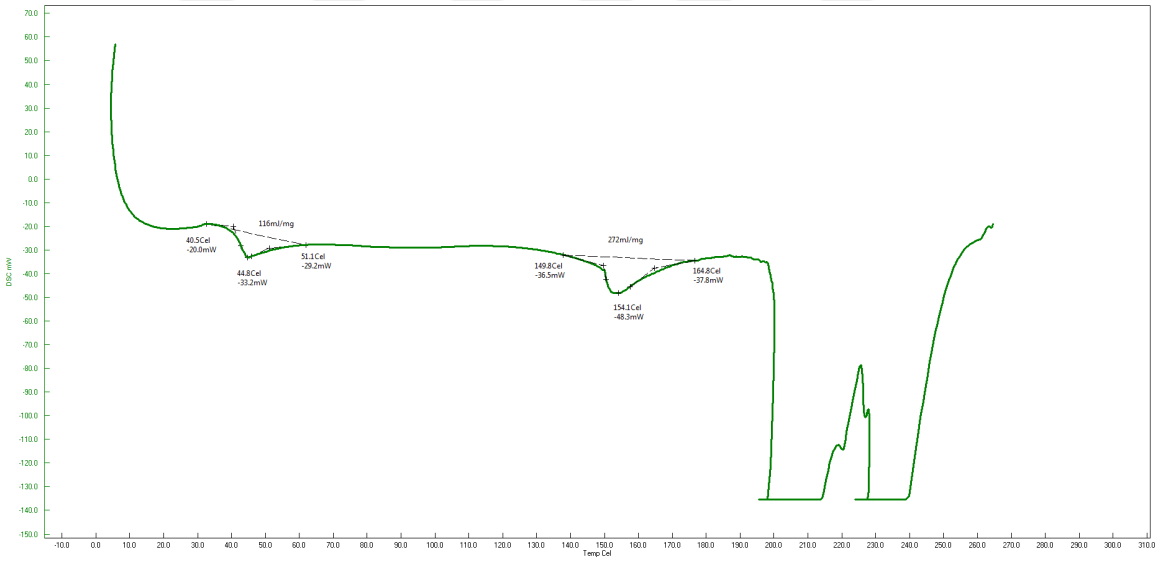


Figure 3-74: DSC Analysis spectra of bleached x1 hair samples treated with mineral oil

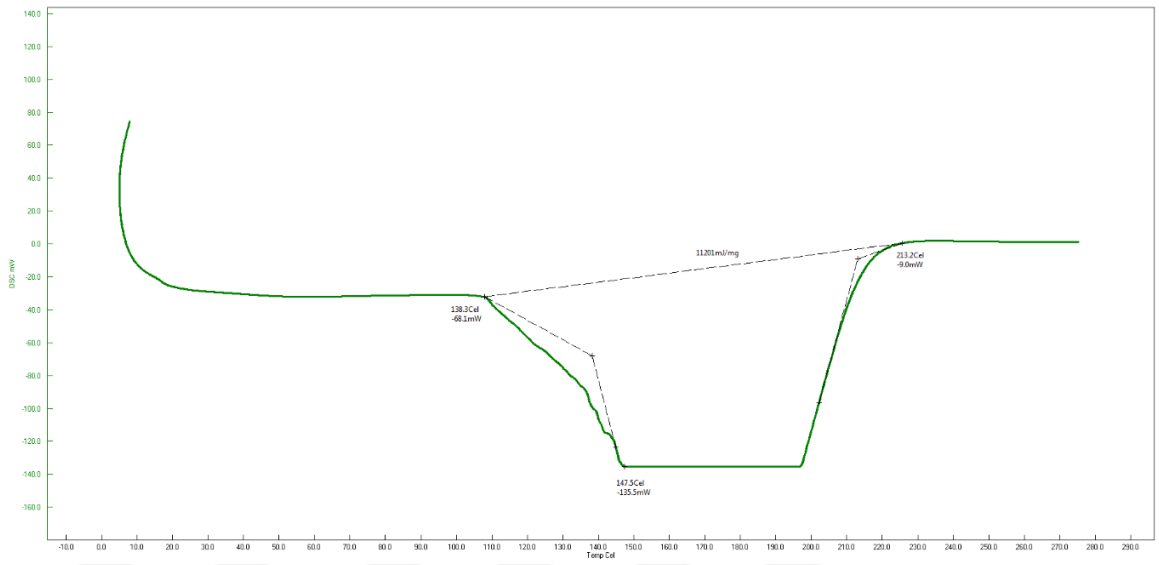


Figure 3-75: DSC Analysis spectra of virgin hair samples treated with coconut oil

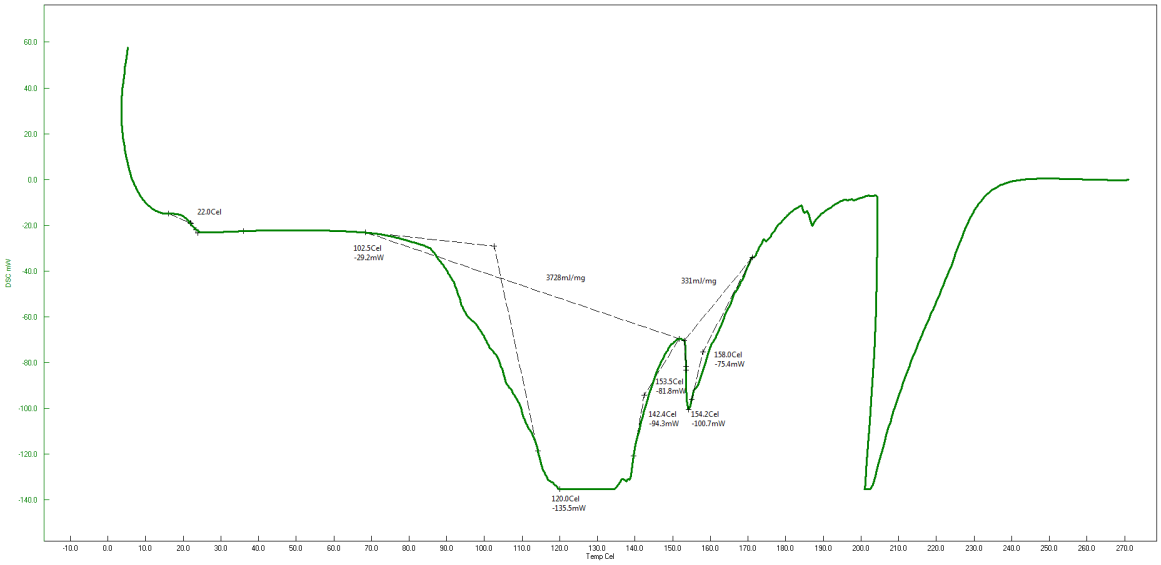


Figure 3-76: DSC Analysis spectra of bleached x1 hair samples treated with coconut oil

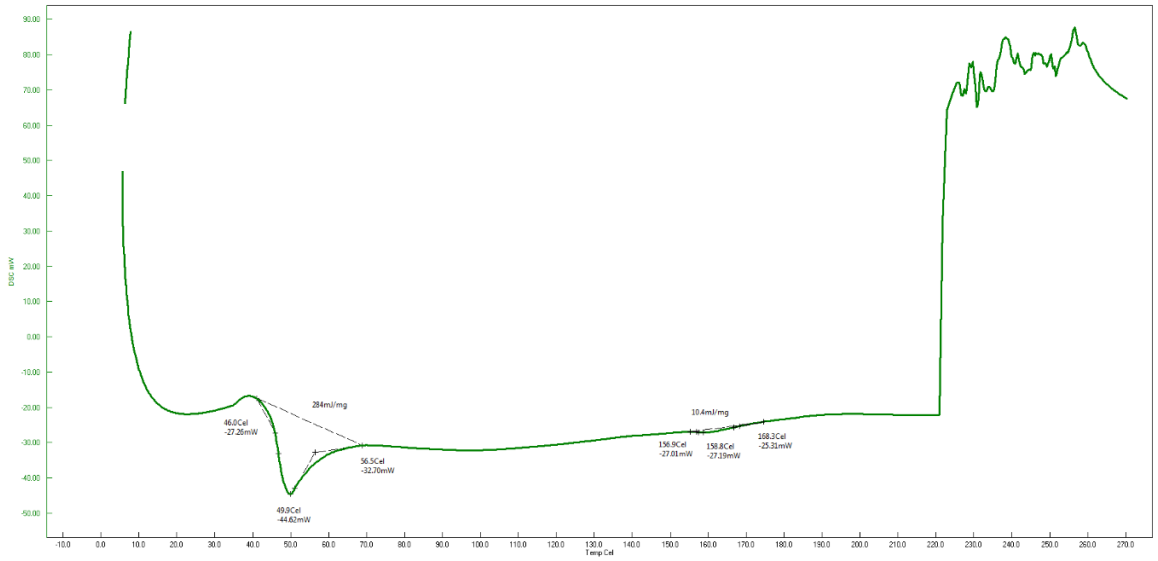


Figure 3-77: DSC Analysis spectra of virgin hair samples treated with linseed oil

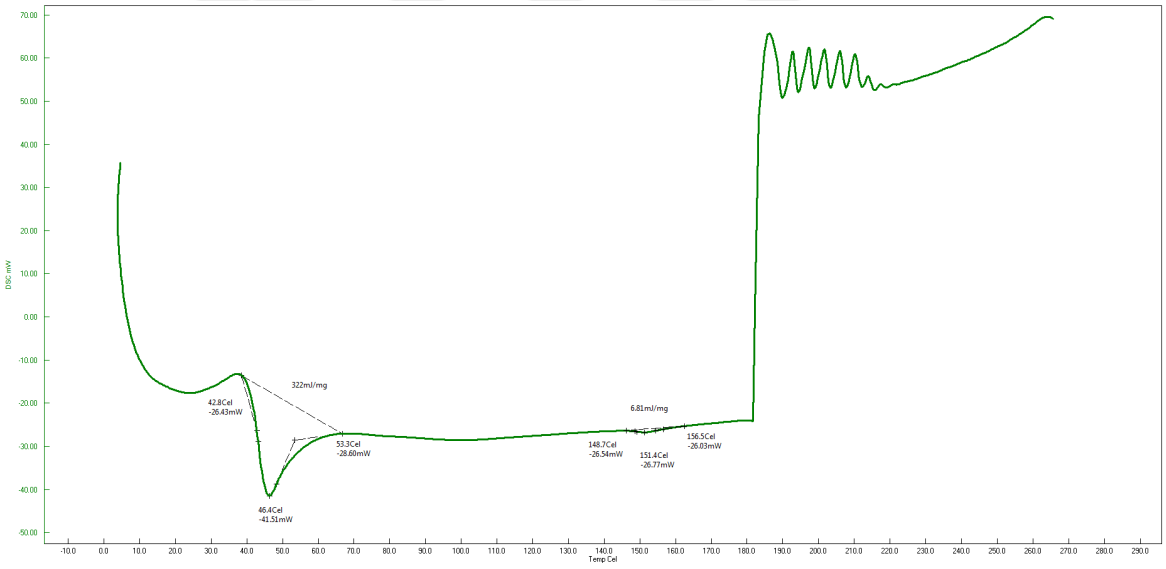


Figure 3-78: DSC Analysis spectra of bleached x1 hair samples treated with linseed oil

4 DISCUSSION

4.1 FLOURESCENCE MICROSCOPY

4.1.1 The Positive Control and Negative Control

As shown in figure 3-1; mineral oil was not able to penetrate into the cortex, but clear rings of dye were seen on the outside of the hair fiber indicating that the oil only stayed in cuticle. Similar results were reported by other researchers as they indicated that mineral oil does not penetrate into hair cortex [72, 108]. This is mainly due to the fact that mineral oil is nonpolar, contains long linear carbon chains with length of above C20 [73]. In this study, mineral oil was used as a negative control and results agreed with reported results. On the other hand, coconut oil penetrated into hair cortex as shown in figure 3-4. Coconut oil has been known as one of the penetrating oils and it has been therefore widely used as a hair care oil in several countries [72, 77]. Many researchers have reported good penetration of coconut oil into hair cortex [71, 108]. In this study coconut oil was used as a positive control and results agreed with the earlier reported results. Coconut oil is composed of relatively lower fatty acids. It contains mainly lauric acid (C12; 49%) and myristic acid (C14; 22%). It also contains in lower amounts of capric acid (C10; 5%) and palmitic acid (C16; 8.4%). Since the majority of the fatty acids of coconut oil are low carbon, straight chain fatty acids with no double bonds, they are more readily available for penetration [73]. When the penetration studies for both positive and negative controls were repeated with bleached hair fibers, all of the results showed penetration into the cortex as shown in figures 3-2, 3-3, 3-5, and 3-6. This was due to the damage caused to the cuticle of the hair fibers. Bleaching oxidizes thioester bonds between cuticle cells as well as cystine in cystine reach regions as the A-layer and exocuticle causing deterioration of cell membrane complex [55, 59]. The number of cycles of bleaching may have increased the penetration but it was not possible to quantify the differences This could be because of the nature of the bleaching process; even one bleaching was strong enough chemical treatment which really caused enough damage in the cuticle and cortex of the hair. The procedure used in this experiment was stronger than the regular dying process. From these results we could conclude that even one cycle of bleaching damaged the cuticle and cortex as mentioned in the literature therefore, one cycle of bleaching or more cycles of bleaching did not show any significantly different results. In all cases, because of

the damaged cuticle all of the oils penetrated into the cortex without any difference which could be related to the oils. In other words, this clearly indicated that when cuticle is damaged because of chemical treatments, the type / composition of the oil was not a determining factor in the penetration of the oils into the hair cortex.

4.1.2 Linseed Oil

When virgin hair treated with linseed oil, there was a penetration into the cortex, (figure 3-7). Linseed oil is mainly composed of linolenic acid (C18:3) and had double bonds. Our study clearly indicated that linseed oil could be qualified as a penetrating oil like coconut oil although it contained longer chain length fatty acids and double bonds. This was not in compliance with the general view. Our studies showed that, linseed oil can be used as a hair treatment oil or incorporated into other hair care products. As seen with mineral and coconut oils, whenever hair was bleached once or seven times, linseed oil penetrated into the cortex because of the damaged cuticle not having its barrier function anymore (figures 3-8 and 3-9).

4.1.3 Almond Oil

According to this study, almond oil also can also be used for hair care purposes as it showed penetration into virgin hair cortex under florescence microscopy, as can be seen in figure 3-10. When the composition of the almond oil is taken into account, it could be put under non-penetrating oil category, because an average composition of almond oil is: 62-86% oleic acid (C18:1), 7-30% linoleic acid (C18:2), 4-9% palmitic acid (C16:0) and a little of palmitoleic acid (C16:1), stearic acid (C18:0). The specific brand of almond oil we used in our study reported the composition of the particular batch as 74,11% oleic acid (C18:1), 16,70% linoleic acid (C18:2), 6% palmitic acid (C16:0) and ,16% stearic acid (C18:0). Based on our results, we again report that almond oil is one of the penetrating oils we used in our study. Based on the composition, it seems that penetration could not be controlled only with the chain length of the fatty acids composing the oils and / or with the presence of the double bonds. In Turkish tradition, in fact, Almond oil is one of the oils recommended as hair / skin treatments. We concluded again that further studies need to be conducted in order to explain the mechanism of the penetration of oils into the cortex.

Similar to the previously studied oils, almond oil penetrated into the cortex of bleached once and bleached seven times hair filaments due to the same reason as explained above (Figures 3-11 and 3-12).

4.1.4 Baobab Oil

As shown in figure 3-13, baobab oil behaved similar to mineral oil. The oil clearly stayed on the cuticle and did not penetrate into the cortex of virgin hair. Baobab is one of the oils introduced recently into the market as a candidate for hair and skin care oil. The composition of baobab was reported to be 39% oleic acid (C18:1), 27% linoleic acid (C18:2), 25% palmitic acid (C16:0) and 5% stearic acid (C18:0). This oil is different from all others, similarities and differences can be seen when compared with coconut, almond and linseed oils in terms of chain length of fatty acids composition. For example, lower chain length of palmitic acid was higher in baobab oil than almond oil suggesting that penetration of baobab oil would have been easier. On the other hand, linoleic acid content of baobab is higher than almond oil and this may have had an unfavorable effect on penetration. Again, when hair is bleached, baobab oil was also able to reach the cortex (Figures 3-14 and 3-15), suggesting strongly that the cuticula of the hair has a strong barrier function.

Based on our findings, we can conclude that penetration of oils into the hair cortex cannot be easily explained just because of the chain lengths as well as the number of the double bonds contained in the fatty acid/ triglyceride chains. When earlier studies were searched thoroughly in order to compare the results, it was noted that the number of oils used in penetration studies were limited. In most of the studies mentioned earlier, penetration of an oil was investigated together with a known positive (coconut oil) and negative (paraffin oil), and results were explained more easily. Most of the other studies extensively investigated the effect of the oils on mechanical properties of the hair, but these results were not related to penetration ability of the oils used in the studies. Further research is required to better understand these complex effects of oils. Most probably the ability of various oils to penetrate into the cortex is related to their molecular characteristics, such as surface energy, cohesive forces, and surface attaching conformation, diffusion characteristics through cuticula lipids, ability to bind the cortex proteins and more not investigated up to this date. There is no doubt that one of the main characteristics of the oils to affect its penetrability

into cortex could be its ability to diffuse through the cuticula layer of hair, however any properties to facilitate or promote this permeation process requires further investigation.

4.2 TENSILE STRENGTH

As a general rule, bleaching reduces stress at break forces because of the damage caused to disulfide bonds [55]. It has a negative effect on stress at break due to damage given to hair fibers. The main goal in bleaching hair is to lighten the hair, and this purpose is mainly achieved by oxidation [55]. In spite of this, hair proteins are also affected by side reactions due to the severe reaction conditions needed for the devastation of hair pigments chromophoric groups, and because of the proteinaceous structure of hair, it has a considerable portion of oxidizable groups [55]. Hair has thioester bonds in between the cuticle cells, as well as on the surface of them. It also includes disulfide bonds of both cuticle proteins and cortical matrix. As the mentioned groups are part of the hair structural proteins, bleaching also causes degradation to these proteins [55], nevertheless, hair strength is mainly accredited to the cortex which is responsible for the hair mechanical properties and forms the bulk of the fiber [75]. In this study, it was clearly seen that the more the hair was bleached, the lower the stress at break point was for all of the studied samples and oils, as shown in table 3-1 and corresponding figures. These results were in agreement with all other studies and treatment with the oils also showed similar results with other studies [109] except for baobab oil, so that all the other oils used in this study improved the stress at break point when compared to baseline for both virgin and bleached hair. Baobab oil, on the other hand, had no statistically significance different effect on virgin hair stress at break point, but it noticeably increased its value for bleached hair.

4.2.1 Mineral Oil

In our study, mineral oil was used as negative control. When compared to its corresponding sample, mineral oil had no statistically significant difference on improving the strength of the studied samples in neither on virgin nor on bleached cases as shown in tables 3-28, 3-33, 3-38, 3-43, 3-48 and their corresponding figures. This corresponds to the results in a previous study were it showed that mineral oil had no statistically significance effect on the tensile strength of the hair [75].

4.2.2 Coconut Oil:

Coconut oil, our positive control, had a positive statistically significance effect on the tensile strength of all our studied samples as shown in tables 3-29, 3-34, 3-39, 3-44, 3-49 and their corresponding figures. According to our study and to previous studies as discussed earlier, coconut oil was able to penetrate into the cortex, and as it has high affinity towards hair proteins [72], causing a statistically significant improvement to treated samples stress at break points.

4.2.3 Linseed Oil:

As shown in tables 3-30, 3-35, 3-40, 3-45, 3-50 and corresponding figures, linseed oil improved the stress at break points for all studied samples in both virgin and bleached cases. As linseed oil was able to penetrate into hair cortex as shown in fluorescence microscopy experiment, this corresponds to the fact that oils diffusing into hair cortex can increase strength of the hair [75].

4.2.4 Almond Oil:

Tables 3-31, 3-36, 3-41, 3-46, 3-51 and their corresponding figures shows that almond oil had statistically significant improvement on the stress at break points for all studied samples in both virgin and bleached hair samples. Also, almond oil was able to penetrate into hair cortex as shown in fluorescence microscopy experiment. This again corresponded to the fact that when oil diffuses into hair cortex it increases strength of the hair [75].

4.2.5 Baobab Oil:

Table 3-32 shows that when virgin hair was treated with baobab oil, the stress at break point was improved by almost 7 G-force/cm^2, with a P value of 0.45 which makes it statistically significant difference, yet at the line. According to our study, baobab oil was not able to penetrate into the cortex of virgin hair, meaning that it was not supposed to affect the stress at break point of virgin hair. When compared to the changes caused by other oils and baobab oil on the bleached hair which was able to penetrate into its cortex, it is seen that it improved the stress at break point by about 50-60 G-force/cm^2, tables 3-37, 3-42, 3-47, and 3-52, leading to the conclusion that the change to the stress at break point of virgin hair

treated with baobab oil is probably due to other reason which cannot be explained only by penetration into the cortex.

4.3 COMBING FORCES

As shown in figure 3-36, the more times the hair was bleached, the higher the max load value was obtained in combing tests. This is due to the damage caused to the cuticle due to the repeated bleaching. As the resistance to combing is a matter of hair cuticle due to its scale shape and geometry and has nothing to do with the cortex [1], it is expected to see that all of the oils used noticeably decreased combing forces compared to non-treated baselines, due to the lubricating effect of the oily layer formed over the hair fiber. It was also noticed that for both oil treated and non-treated hair switches, the max load was always near the tip-end. Figure 3-35 shows that almond oil, even with a very little margin when compared to the other oils used, always decreased the max load to minimum in all samples. All the other oils decreased the max load in different percentages.

4.4 GROOMING

Table 3-17 illustrates typical repeated grooming data for virgin hair, bleached once hair, bleached four times hair, and bleached 7 times hair fibers including non-treated baseline, and hair treated with all the oils used in this study. It clearly shows that in all studied cases, the first 1000 combing caused the most hair breakage, and the number decreases as the grooming cycles advance. This could probably be because of the weakest and most fragile hair fibers were broken during the first 1000 combing cycles. These results complied with previous studies, for example; Evans and Park also found that the first 1000 brushing strokes caused the most hair breakage [92]. It also shows that all of the tested oils caused a reduction in hair breakage up to 5000 brushing strokes. This reduction was noticed for both virgin hair and bleached hair swatches as shown in figure 3-38. This must be due to the lubricating effect of the oils and film forming around hair fibers which causes ease of combing and less tendency to tangle forming. The collected data were used to predict hair fiber breakage possibility as a function of combing strokes by creating survival probability plots (figures 3-39 to 3-62) and by using these results, we were able to predict that, for virgin non-treated hair, around 1000 combing strokes are needed to produce 0.5% likelihood of breakage, and almost 4300 combing strokes to produce 1% likelihood of breakage. These numbers however

are not the same when oil is applied; when mineral oil is applied, 1000 combing strokes would produce approximately 0.33% likelihood of breakage, and 4300 combing strokes would produce almost 0.68% breakage likelihood, table 3-19. Coconut oil, linseed oil, almond oil, and baobab oil all reduced the breakage likelihood to somewhere between 0.26% to 0.30% at 1000 combing strokes and between 0.55% to 0.61% at 4300 combing strokes, tables 3-20, 3-21, 3-22, and 3-23 respectively. Figure 3-37 illustrates that for non-treated hair and oil treated hair, bleaching clearly increased the number of broken hair fibers after repeated grooming. This higher breakage incidence occurs due to chemical damage caused to hair as a result of bleaching.

4.5 POROSITY

Figures 3-69 through 3-78 represents the data of the weight loss of studied samples. This data showed had meaningful explanation and it could not be explained by the penetration or no-penetration of the oil into the hair fibers. There seems to be other chemical, physiochemical, or structural effects leading to these results. Thus, the results of this experiment are not to be included in the conclusion of this study.

4.6 DIFFERENTIAL SCANNING CALORIMETRY

Although DSC is used extensively to investigate the effectiveness of hair conditioning treatments, our results clearly showed that not only the interpretation of the thermograms but also finding the most appropriate protocol for the testing alone is rather difficult. In terms of the peak temperatures of the endothermic peak / enthalpy values, obtaining statistically significant differences or staying within acceptable level of standard error conditions is not very easy, since the different experimental conditions give different results. One may obtain good agreement between the results of same conditions (table 3-128, Table 3-129 and Table 3-130). Commonly used method of dry closed pan method most of the time masked the earlier peaks which seem to be more important in our studies.

As shown in table 3-128, Table 3-129 and Table 3-130, bleaching once, 4 times and 7 times had a clear effect on the peak temperatures in all methods used. However, in dry pan conditions, except for one case denaturation of alpha-helices were not identified, only pyrolysis peaks were seen on the thermograms. The wet pan / pressurized pan experiments

yielded clear endothermic peaks due to aggregation and unfolding of alpha-helices, probably all available bonds (di-sulfide and ionic bods) become more free and more easily moving. The results are in agreement with the literature that cosmetic treatments like bleaching decreased the T_g peak temperatures and the more the temperature is decreased the more the damage is.

When oils are applied on the hair samples, there were no increase of peak temperatures were observed. In cosmetic industry, increase in T_g is regarded as a repair. Whether strong covalent bonds are re-established or not or the protein structure is repaired, DSC results are used for claims substantiation. In our opinion, DSC alone may not be the best method to make strong claims about cosmetic hair repairing, also care should be taken in interpretation of the thermograms.

5 CONCLUSION

This research aimed to investigate the penetration abilities of linseed oil, almond oil, and baobab oil into the cortex of human hair, along with the damage caused to hair due to repeated bleaching, and how can those oils restore hair properties. Penetration studies were conducted by using fluorescence microscopy. Hair cross sections were examined after treating them with the oils that are labelled with a florescent dye. Florescent dye and oil penetration into the hair cortex is monitored with a microscope. Penetration of the experimental oils are compared with the positive control, coconut oil, and negative control, mineral oil. Bleaching damages hair and oils' offer benefits to the hair especially improving tensile strength, combing forces and repeated grooming.

It can be concluded that two of the studied oils; linseed oils and almond oil, were able to penetrate into virgin hair cortex, whereas baobab oil was not. Bleaching hair caused real damage to the hair cuticle layer allowing all the oils, even mineral oil, to penetrate into the cortex of the hair. All of the oils tested caused combing forces to reduce due to lubricating effect and film forming properties, but coconut oil, linseed oil and almond oil were able to statistically improve the tensile strength of virgin hair as well. Hair breakage due to repeated grooming was also reduced by all of the oils.

Although mechanical strength tests may indicate beneficial effects of the hair care products, penetration has to be monitored by means of more reliable objective tests.

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7 APPENDICES

Appendix A1

petrol yağ
LUBRICANTS

13.06.2019

PY/145

TARİŞ İNCİR

To whom it may concern,

We hereby declare that our product OYSTER 193 (Paraffinum Liquidum) is 100% medicinal grade paraffinic white oil. It conforms to European Pharmacopeia requirements and the product has CAS number, 8042-47-5.

Sincerely yours,

petrol yağ
LUBRICANTS
Petro Yağ ve Kimyasalları San. ve Tic. A.Ş.
GOSB Tambalova Alanı 6. Cad. Cd 32. Sk. No:1 GOSB Gebze/Kocaeli
İlyasbey V.D. 725 039 0423 Ticaret Sicil No: 20188

Gürcan VARLI

Business Development Specialist

Appendix A2

ANALYTICAL REPORT

SAMPLE NOT DRAWN BY QUALITY TESTING LABORATORY, CDB

Sample Submitted and Identified by Supplier as	Virgin Coconut Oil (Batch No: KAF/001/11-17)
Sampling Method	NA
Sample Description/ Condition	Packed in PET Bottle
Sample Quantity	250 ml
Sample Received: 02.11.17 Test start date: 03.11.17 Test end date:10.11.17	

RESULT OF ANALYSIS

Sl. No	Test Requirements	Protocol	Result
1.	*Unsaponifiable Matter	IS: 548 part I, 1964	0.29 %
2.	* Fatty Acid Composition	AOCS Official method 5th Edtn. Ce 1-62	
a)	Caproic acid		0.503 %
b)	Caprylic acid		6.204 %
c)	Capric acid		5.129 %
d)	Lauric acid		50.020 %
e)	Myristic acid		20.212 %
f)	Palmitic acid		8.240 %
g)	Oleic acid		5.120 %
h)	Linoleic acid		1.021%
i)	Stearic acid		3.214 %

The parameters marked with an * are not accredited by NABL

Appendix A3

1888'den beri Helvacizade

ZADE VITAL İLAÇ KİMYA GIDA SAN. VE TİC. A.Ş.
SOĞUK PRES YAĞ KONTROL SERTİFİKASI
ZADE VITAL PHARMA CHEMICALS & FOOD INC.
COLD PRESSED OIL CONTROL CERTIFICATE

ZADE|VITAL NUTRITIONAL SUPPLEMENTS

Ürün ismi *(Product name)* :	**SOĞUK PRES KETEN TOHUMU YAĞI** *(COLD PRESSED LINSEED OIL)*	Üretici *(Manufacturer)* :	**ZADE VİTAL**
Ürün Kod no *(Product Code no)* :	YAG_003	Üretim tarihi *(Manufacture date)* :	04.2019
Parti no *(Batch no)* :	900302	Son kullanma tarihi *(Expiry date)* :	04.2022
Doküman kod no *(Document code no)* :	KM_YAG-003_01_SER	Numune alma tarihi *(Sampling date)* :	09.04.2019
Saklama koşulları & önlemler *(Storage conditions & precautions)* :	25°C'nin altında ki oda sıcaklığında ışıktan koruyarak saklayınız. *(Keep away from sunlight and store at room temperature below 25°C)*		

	ANALİZ PARAMETRELERİ	*ANALYSIS PARAMETERS*	SPESİFİKASYONLAR *SPECIFICATION*	SONUÇLAR RESULTS	BİRİM *UNIT*	METODLAR *METHODS*
1.	Görünüş	*Appearance*	Berrak, sarı veya kahverengimsi sarı sıvı *Clear, yellow or brownish yellow liquid*	Uygun *Complies*		Organoleptic
2.	Koku	*Odor*	Kendine özgü *Charecteristic*	Uygun *Complies*		Organoleptic
3.	Tat	*Taste*	Kendine özgü *Charecteristic*	Uygun *Complies*		Organoleptic
4.	Yağ Asit Kompozisyonu	*Fatty Acid Composition*			% Alan *Area %*	Firma içi metod *Inhouse method*
		< C 16:0 :	Max. 1.00	0.06		
		Palmitic Acid C 16:0 :	3.00 – 8.00	5.35		
		Palmitoleic Acid C16:1 :	Max. 1.00	0.07		
		Stearic Acid C 18:0 :	2.00 – 8.00	5.64		
		Oleic Acid C 18:1 :	11.00 – 35.00	22.05		
		Linoleic Acid C 18:2 :	11.00 – 24.00	15.62		
		Linolenic Acid C 18:3 :	35.00 – 65.00	50.26		
		Arachidic Acid C 20:0 :	Max. 1.00	0.19		
5.	Asit değeri	*Acid value* :	Max. 4.5	2.0	mg KOH / g yağ *(oil)*	Ph. Eur. 2.5.1
6.	Kırılma İndisi	*Refractive Index* :	~ 1.480	1.4800	(20°C)	Ph. Eur. 2.2.6
7.	Peroksit	*Peroxide Value* :	Max. 15.0	5.5	meqO_2 / kg yağ *(oil)*	Ph. Eur. 2.5.5
8.	Sabunlaşmayan Madde Miktarı	*Unsaponification Matter* :	Max. 1.5	0.6	%	Ph. Eur. 2.5.7
9.	Sabunlaşma Sayısı	*Saponification Value* :	188.0 – 195.0	193.0		Ph. Eur. 2.5.6
10.	İyot Sayısı	*Iodine Value* :	160.0 – 200.0	175.0	Wijs	Ph. Eur. 2.5.4
11.	Özgül Ağırlık	*Relative Density* :	~ 0.931	0.930	(20°C) g/ml	Ph. Eur. 2.2.5
12.	Kadmiyum	*Cadmium* :	Max. 0.5	< 0.5	ppm	Ph. Eur. 2.4.27
13.	Su İçeriği	*Water Content* :	Max. 0.10	0.02	%	Ph. Eur. 2.5.32
14.	Mikrobiyal Kontaminasyon	*Microbial Contamination*				Ph. Eur. 2.6.12, 2.6.13, 5.1.4, 5.1.8
		TAMC :	Max. 10^4	< 10^4	cfu / g	
		TYMC :	Max. 10^2	< 10^2	cfu / g	
		Bile-tolerant gram-negative bacteria :	Max. 10^2	< 10^2	cfu / g	
		Escherichia coli :	Negative / g	Negative		
		Salmonella :	Negative /25 g	Negative		

KARAR *(RESULT)*:	ANALİZİ YAPAN *(ANALYSED BY)*		KONTROL EDEN *(CONTROLLED BY)*	ONAYLAYAN *(APPROVED BY)*
	ADI/SOYADI/TARİH/İMZA (NAME/SURNAME/DATE/SIGNATURE)		*ADI/SOYADI/TARİH/İMZA (NAME/SURNAME/DATE/SIGNATURE)*	*ADI/SOYADI/TARİH/İMZA (NAME/SURNAME/DATE/SIGNATURE)*
[V] UYGUN *(APPROVED)*	Kalite Kontrol Analisti *Quality Control Analyst* Zeliha SARI 15.04.2019	Mikrobiyoloji Laboratuvar Sorumlusu *Microbiology Labratory Responsible* Şeyma AKALIN BENDERLİ 15.04.2019	Kalite Kontrol Sorumlusu *Quality Control Responsible* Ali GÖKYER 15.04.2019	Kalite Güvence Sorumlusu *Quality Assurance Responsible* Gizem KAHRAMAN 15.04.2019
[ ] UYGUN DEĞİL *(NOT APPROVED)*				
AÇIKLAMA *(EXPLANATION)*				

Sayfa (page) 1 / 1

Appendix A4

Helvacizade

KONTROL SERTİFİKASI
CONTROL CERTIFICATE

Sayfa No (Page No): 1 / 1

Yağ İsmi *(Oil Name)*	:	**Badem Yağı** *Almond Oil*	Üretici *(Manufacturer)*	:	HELVACIZADE A.Ş
Yağ Kod No *(Oil Code No)*	:	YAG_018	Üretim Tarihi *(Manufacture Date)*	:	06.03.2017
Kontrol No *(Control No)* /	:	018703	Son Kullanma Tarihi *(Expiry Date)*	:	06.03.2019
Parti Büyüklüğü *(Batch Size)*	:	***(U.Y) ****(N/A)	Numune Alma Tarihi *(Sampling Date)*	:	06.03.2017
Sevk Miktarı (Delivery Amount)	:	***(U.Y) ****(N/A)	Doküman Kod No *(Document Code No)*	:	KM_YAG -018_00_SER
Ambalaj Formu *(Packaging)*	:	100 mL Cam Şişe *(Glass Bottle)*			
Saklama Koşulları & Önlemler *(Storage Conditions & Precautions)*	:	25 °C nin altındaki oda sıcaklığında ışıktan koruyarak saklayınız. (*Keep away from sunligt and store at room temperature below 25 °C.)*			

	YAPILAN KONTROLLER *(CONTROL PARAMETERS)*		SPESİFİKASYONLAR *(SPECIFICATIONS)*	SONUÇLAR *(RESULTS)*	DEĞERLENDİRME (EVALUATION)	
1.	**Yağ Asit Kompozisyonu** *(Fatty Acid Composition)*					
	Palmitik Asit *(Palmitic Acid)* **C 16:0**	:	%4,50 - %10,00	%6,00	[√] U *(A)	[ ] U D **(N A)
	Stearik Asit *(Stearic Acid)* **C 18:0**	:	%1,00 - %4,00	%2,16	[√] U *(A)	[ ] U D **(N A)
	Oleik Asit *(Oleic Acid)* **C 18:1**	:	%55,00 - %80,00	%74,11	[√] U *(A)	[ ] U D **(N A)
	Linoleik Asit *(Linoleic Acid)* **C 18:2**	:	%15,00 - %35,00	%16,70	[√] U *(A)	[ ] U D **(N A)
	Linolenik Asit *(Linolenic Acid)* **C 18:3**	:	Maks. %0,70	%0,07	[√] U *(A)	[ ] U D **(N A)
	Araşidik Asit *(Arashidic ,Acid)* **C 20:0**	:	Maks. %0,50	%0,08	[√] U *(A)	[ ] U D **(N A)
	Eikosenik Asit *(Eicosenic Acid)* **C 20:1**	:	Maks. %0,40	%0,05	[√] U *(A)	[ ] U D **(N A)
	Behenic Asit *(Behenic Acid)* **C 22:0**	:	Maks. %0,30	%0,02	[√] U *(A)	[ ] U D **(N A)
2.	**FFA (% Oleik Asit Cinsinden-** *%Oleic acid)*	:	Maks. %4,00	%2,00	[√] U *(A)	[ ] U D **(N A)
3.	**Kırılma İndisi** *(Refractive Index)*	:	1,4620 - 1,4690	1,4635	[√] U *(A)	[ ] U D **(N A)
4.	**Peroksit** *(Peroxide Value)*	:	Maks. 15,0 meqO_2 / kg	7,8 meqO_2 / kg	[√] U *(A)	[ ] U D **(N A)
5.	**Sabunlaşmayan Madde Miktarı** *(Unsaponification Matter)*	:	Maks. 15,0 g/kg	5,6 g/kg	[√] U *(A)	[ ] U D **(N A)
6.	**Sabunlaşma Sayısı** *(Saponification Value)*	:	185,0 – 200,0	190,0	[√] U *(A)	[ ] U D **(N A)
7.	**İyot Sayısı** *(Iodine Value)*	:	90,0 Wijs – 110,0 Wijs	100,0 Wijs	[√] U *(A)	[ ] U D **(N A)
8.	**Görünüş** *(Appearance)*	:	Sarı, berrak sıvı *(Yellow ,Clear Liquid)*	Sarı, berrak sıvı *(Yellow ,Clear Liquid)*	[√] U *(A)	[ ] U D **(N A)
9.	**Özgül Ağırlık** *(Relative Density)*	:	0,912 g/cm^3 – 0,926 g/cm^3	0,918 g/cm^3	[√] U *(A)	[ ] U D **(N A)
10.	**Koku** *(Odor)*	:	Kendine özgü *(Characteristic)*	Kendine özgü *(Characteristic)*	[√] U *(A)	[ ] U D **(N A)
11.	**Tat** *(Taste)*	:	Kendine özgü *(Characteristic)*	Kendine özgü *(Characteristic)*	[√] U *(A)	[ ] U D **(N A)
12.	**Mikrobiyal Kontaminasyon** *(Microbial Contamination)*					
	TAMC	:	Maks. 10^4 CFU/g	10^4 CFU/g	[√] U *(A)	[ ] U D **(N A)
	TYMC	:	Maks. 10^2 CFU/g	10^2 CFU/g	[√] U *(A)	[ ] U D **(N A)
	Bile-tolerant gram-negative bacteria	:	Maks. 10^2 CFU/g	10^2 CFU/g	[√] U *(A)	[ ] U D **(N A)
	Escherichia coli	:	Olmamalı/ g *(Absent / g)*	Yok. *(Absent)*	[√] U *(A)	[ ] U D **(N A)
	Salmonella	:	Olmamalı/25 g *(Absent / 25g)*	Yok. *(Absent)*	[√] U *(A)	[ ] U D **(N A)

*(A): APPROVED
**(N A): NOT APPROVED
***(U.Y): UYGULAMASI YOK
****(N/A): NO APPLCATION

KARAR *(DECISION)*	ANALİZİ YAPAN *(ANALYSED BY)*	KONTROL EDEN *(CONTROLLED BY)*	ONAYLAYAN *(APPROVED BY)*
	ADI/SOYADI/TARİH/İMZA (NAME/SURNAME/DATE/SIGNATURE)	*ADI/SOYADI/TARİH/İMZA (NAME/SURNAME/DATE/SIGNATURE)*	*ADI/SOYADI/TARİH/İMZA (NAME/SURNAME/DATE/SIGNATURE)*
[√] UYGUN *(APPROVED)*	Kalite Kontrol Analisti *Quality Control Analyst* Nihal İLHAN 03.04.2017	Mikrobiyoloji Laboratuvar Sorumlusu *Microbiology Labratory Responsible* Şeyma AKALIN BENDERLİ 03.04.2017	Kalite Kontrol Sorumlusu *Quality Control Responsible* Ali GÖKYER 03.04.2017	Mesul Müdür *Responsible Manager* Burak DÜRÜS 03.04.2017
[ ] UYGUN DEĞİL *(NOT APPROVED)*				
AÇIKLAMA *(EXPLANATION)*	: ***(U.Y) ****(N/A)			

Appendix A5

neotron SPA
ANALYTICAL AND TECHNICAL SERVICES

QS-feedmonitoring
QS-residuemonitoring
QS-Labor für Frisches Obst, Gemüse und Kartoffeln.
QS-Labor für Futtermittel.

ACCREDIA L'ENTE ITALIANO DI ACCREDITAMENTO
LAB. N°0026
Signatory of EA, IAF and ILAC Mutual Recognition Agreements

Neot-dir/008/86 ed.8 01/07/2010

CUSTOMER
BAOBAB FRUIT COMPANYSENEGAL S.A.R.L.
Quartier 10ème ex Riaom
BP826 THIES SENEGAL

Modena (Italy), li 16/06/2015

Analysis beginning date
29/05/2015

TEST REPORT nr. 15E16625-In-0

SAMPLE **15E16625**

Description provided by Customer: OBO-BIO ORGANIC BAOBAB OIL COLD PRESSED Batch code:: BLEND 2015
Extranet request n° N0010/15 - 28/05/2015 08:43:12. - Sample arrived on the 29/05/2015 - Sampling by: Customer - Transport by: Corriere
Sample Condition on Receipt: Room temperature

ANALYSIS DESCRIPTION	RESULT	U	REC. %	UNIT OF MEASURE	LQ	LD	METHOD	ANALYSES ENDING DATE
Iodine number	84,4						★ ISO 3961:2013 - Titrimetrico	09/06/2015
Saponification number	186,2			mg KOH/g			★ A-S-G	09/06/2015
Density at 20 °C	0,910			g/ml			★ PESO SPEC 2014 Rev.0 - Gravimetric	10/06/2015
Refractive index	1,46965 (a 20°C)						NGD C 31 - 1976 - Rifrattometrico	09/06/2015
NUTRITIONAL ANALYSIS (Single Parameters)								
Moisture	< LQ			g/100 g	0,1		07(S49) 2013 Rev.9 - Gravimetric	05/06/2015
Flash point [AE]	See enclosure						★ E-MCP	11/06/2015
HEAVY METALS DETERMINATION								
Arsenic as As	< LQ			mg/kg	0,005		05(ICP-MS) 2012 Rev.1 - ICP massa	04/06/2015
Cadmium as Cd	< LQ			mg/kg	0,005		05(ICP-MS) 2012 Rev.1 - ICP massa	04/06/2015
Mercury as Hg	< LQ			mg/kg	0,005		05(ICP-MS) 2012 Rev.1 - ICP massa	04/06/2015
Lead as Pb	< LQ			mg/kg	0,005		05(ICP-MS) 2012 Rev.1 - ICP massa	04/06/2015
FATTY ACIDS COMPOSITION BY GC CAPILLARY								
Butyric Acid (C4:0)	< LQ			%	0,05		07(S46) rev10 2012 - GC-FID	15/06/2015
Caproic Acid (C6:0)	< LQ			%	0,05		07(S46) rev10 2012 - GC-FID	15/06/2015
Enanthic Acid (C7:0)	< LQ			%	0,05		07(S46) rev10 2012 - GC-FID	15/06/2015
Caprylic Acid (C8:0)	< LQ			%	0,05		07(S46) rev10 2012 - GC-FID	15/06/2015
Capric Acid (C10:0)	< LQ			%	0,05		07(S46) rev10 2012 - GC-FID	15/06/2015
Decenoic Acid (C10:1)	< LQ			%	0,05		07(S46) rev10 2012 - GC-FID	15/06/2015
Lauric Acid (C12:0)	< LQ			%	0,05		07(S46) rev10 2012 - GC-FID	15/06/2015
Dodecenoic Acid (C12:1)	< LQ			%	0,05		07(S46) rev10 2012 - GC-FID	15/06/2015
Tridecanoic Acid (C13:0)	< LQ			%	0,05		07(S46) rev10 2012 - GC-FID	15/06/2015
12-methyl tridecanoic Acid (C14:0)	< LQ			%	0,05		07(S46) rev10 2012 - GC-FID	15/06/2015
Myristic Acid (C14:0)	0,25	± 0,02		%	0,05		07(S46) rev10 2012 - GC-FID	15/06/2015
13-methyl tetradecanoic Acid (C15:0)	< LQ			%	0,05		07(S46) rev10 2012 - GC-FID	15/06/2015
12-methyl tetradecanoic Acid (C15:0)	< LQ			%	0,05		07(S46) rev10 2012 - GC-FID	15/06/2015
Myristoleic Acid (C14:1)	< LQ			%	0,05		07(S46) rev10 2012 - GC-FID	15/06/2015
Pentadecanoic Acid (C15:0)	0,06	± 0,01		%	0,05		07(S46) rev10 2012 - GC-FID	15/06/2015
14-methyl pentadecanoic Acid (C16:0)	< LQ			%	0,05		07(S46) rev10 2012 - GC-FID	15/06/2015
10-pentadecenoic acid (C15:1)	< LQ			%	0,05		07(S46) rev10 2012 - GC-FID	15/06/2015
Palmitic Acid (C16:0)	25,02	± 0,52		%	0,05		07(S46) rev10 2012 - GC-FID	15/06/2015
15-methyl hexadecanoic Acid (C17:0)	< LQ			%	0,05		07(S46) rev10 2012 - GC-FID	15/06/2015
Palmitoleic acid, including geometrical and positional isomers (C16:1)	0,32	± 0,02		%	0,05		07(S46) rev10 2012 - GC-FID	15/06/2015
14-methyl hexadecanoic Acid (C17:0)	< LQ			%	0,05		07(S46) rev10 2012 - GC-FID	15/06/2015
Heptadecanoic Acid (C17:0)	0,21	± 0,02		%	0,05		07(S46) rev10 2012 - GC-FID	15/06/2015

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neotron SPA
ANALYTICAL AND TECHNICAL SERVICES

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CUSTOMER
BAOBAB FRUIT COMPANYSENEGAL S.A.R.L.
Quartier 10ème ex Riaom
BP826 THIES SENEGAL

Modena (Italy), li 16/06/2015

Analysis beginning date
29/05/2015

TEST REPORT nr. 15E16625-In-0

SAMPLE **15E16625**

ANALYSIS DESCRIPTION	RESULT	U	REC. %	UNIT OF MEASURE	LQ	LD	METHOD	ANALYSES ENDING DATE
Heptadecenoic Acid (C17:1)	< LQ			%	0,05		07(S46) rev10 2012 - GC-FID	15/06/2015
Stearic Acid (C18:0)	4,67	± 0,15		%	0,05		07(S46) rev10 2012 - GC-FID	15/06/2015
Oleic acid, including geometrical and positional isomers (C18:1)	39,05	± 0,48		%	0,05		07(S46) rev10 2012 - GC-FID	15/06/2015
Linoleic acid, including geometrical and positional isomers (C18:2)	27,96	± 0,48		%	0,05		07(S46) rev10 2012 - GC-FID	15/06/2015
Arachidic Acid (C20:0)	1,02	± 0,08		%	0,05		07(S46) rev10 2012 - GC-FID	15/06/2015
11-Eicosenoic Acid (C20:1)	0,15	± 0,02		%	0,05		07(S46) rev10 2012 - GC-FID	15/06/2015
Linolenic acid, including geometrical and positional isomers (C18:3)	0,56	± 0,05		%	0,05		07(S46) rev10 2012 - GC-FID	15/06/2015
Eneicosanoic Acid (C21:0)	< LQ			%	0,05		07(S46) rev10 2012 - GC-FID	15/06/2015
Stearidonic acid (C18:4)	< LQ			%	0,05		07(S46) rev10 2012 - GC-FID	15/06/2015
11,14 eicosadienoic acid (C20:2)	< LQ			%	0,05		07(S46) rev10 2012 - GC-FID	15/06/2015
Behenic Acid (C22:0)	0,41	± 0,05		%	0,05		07(S46) rev10 2012 - GC-FID	15/06/2015
Homo-gamma linolenic acid (C20:3)	< LQ			%	0,05		07(S46) rev10 2012 - GC-FID	15/06/2015
Erucic Acid (C22:1)	< LQ			%	0,05		07(S46) rev10 2012 - GC-FID	15/06/2015
11,14,17 eicosatrienoic acid (C20:3)	< LQ			%	0,05		07(S46) rev10 2012 - GC-FID	15/06/2015
Arachidonic Acid (C20:4)	< LQ			%	0,05		07(S46) rev10 2012 - GC-FID	15/06/2015
Docosadienoic acid (C22:2)	< LQ			%	0,05		07(S46) rev10 2012 - GC-FID	15/06/2015
Lignoceric Acid (C24:0)	0,25	± 0,06		%	0,05		07(S46) rev10 2012 - GC-FID	15/06/2015
Eicosapentaeonic Acid (EPA) (C20:5)	< LQ			%	0,05		07(S46) rev10 2012 - GC-FID	15/06/2015
Nervonic Acid (C24:1)	< LQ			%	0,05		07(S46) rev10 2012 - GC-FID	15/06/2015
Docosatetraenoic acid (C22:4)	< LQ			%	0,05		07(S46) rev10 2012 - GC-FID	15/06/2015
Docosapentaenoic acid (DPA) (C22:5)	< LQ			%	0,05		07(S46) rev10 2012 - GC-FID	15/06/2015
Docosahexaenoic Acid (DHA) (C22:6)	< LQ			%	0,05		07(S46) rev10 2012 - GC-FID	15/06/2015
Other fatty acids	< LQ			%	0,05		* A-GRAS 2014 Rev.1 - GC-FID	15/06/2015
DETERMINATION OF STEROLS COMPOSITION BY CAPILLARY GC (percentage composition)								
Cholesterol (%)	0,08	± 0,06		%	0,05		NGD C71:1989 + NGD C72:1989 - GC-FID	09/06/2015
Brassicasterol (%)	< LQ			%	0,05		NGD C71:1989 + NGD C72:1989 - GC-FID	09/06/2015
24-Methylenecholesterol (%)	0,06	± 0,04		%	0,05		NGD C71:1989 + NGD C72:1989 - GC-FID	09/06/2015
Campesterol (%)	8,28	± 0,25		%	0,05		NGD C71:1989 + NGD C72:1989 - GC-FID	09/06/2015
Campestanol (%)	0,24	± 0,17		%	0,05		NGD C71:1989 + NGD C72:1989 - GC-FID	09/06/2015
Stigmasterol (%)	2,84	± 0,14		%	0,05		NGD C71:1989 + NGD C72:1989 - GC-FID	09/06/2015
Delta-7-campesterol (%)	0,33	± 0,20		%	0,05		NGD C71:1989 + NGD C72:1989 - GC-FID	09/06/2015
Delta-5,23-stigmastadienol (%)	< LQ			%	0,05		NGD C71:1989 + NGD C72:1989 - GC-FID	09/06/2015
Chlerosterol (%)	1,17	± 0,20		%	0,05		NGD C71:1989 + NGD C72:1989 - GC-FID	09/06/2015
Beta-sitosterol (%)	78,4	± 0,6		%	0,05		NGD C71:1989 + NGD C72:1989 - GC-FID	09/06/2015
Sitostanol (%)	1,88	± 0,58		%	0,05		NGD C71:1989 + NGD C72:1989 - GC-FID	09/06/2015
Delta-5-avenasterol (%)	3,79	± 0,34		%	0,05		NGD C71:1989 + NGD C72:1989 - GC-FID	09/06/2015
Delta-7,9, (11)- Stigmastadienol (%)	< LQ			%	0,05		NGD C71:1989 + NGD C72:1989 - GC-FID	09/06/2015
Delta-5,24-stigmastadienol (%)	1,08	± 0,33		%	0,05		NGD C71:1989 + NGD C72:1989 - GC-FID	09/06/2015
Delta-7-stigmastenol (%)	1,10	± 0,14		%	0,05		NGD C71:1989 + NGD C72:1989 - GC-FID	09/06/2015
Delta-7-avenasterol (%)	0,81	± 0,15		%	0,05		NGD C71:1989 + NGD C72:1989 - GC-FID	09/06/2015
Total sterols	426	± 21		mg/100 g			NGD C71:1989 + NGD C72:1989 - GC-FID	09/06/2015

Continued...

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Laboratorio Qualificato D.M. 26-2-87 Art. 4 - Legge 46/82 per la Ricerca Applicata e Innovazione Tecnologica.
Regione Emilia Romagna - AUTORIZZAZIONE Autocontrollo N° 008/MO/008
BNN-Monitoring Fruit and Vegetables Approved Laboratory
I-Monitoring EDEKA AG Fruit and Vegetables Registered Laboratory

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ACCREDIA L'ENTE ITALIANO DI ACCREDITAMENTO
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CUSTOMER
BAOBAB FRUIT COMPANYSENEGAL S.A.R.L.
Quartier 10ème ex Riaom
BP826 THIES SENEGAL

Modena (Italy), li 16/06/2015

Analysis beginning date
29/05/2015

TEST REPORT nr. 15E16625-In-0

SAMPLE **15E16625**

ANALYSIS DESCRIPTION	RESULT	U	REC. %	UNIT OF MEASURE	LQ	LD	METHOD	ANALYSES ENDING DATE
Fatty acids Omega 9								
Erucic acid (C22:1 omega 9)	< LQ			g/100 g			* A-GRAS 2014 Rev.1 - GC-FID	15/06/2015
VITAMIN E - TOCOPHEROLS								
Alpha tocopherol	< LQ			mg/100 g	2,0		07(S124) rev2 2012 - HPLC	09/06/2015
Alpha tocopherol acetate	< LQ			mg/100 g	2,0		07(S124) rev2 2012 - HPLC	09/06/2015
Beta-tocopherol	< LQ			mg/100 g	2,0		07(S124) rev2 2012 - HPLC	09/06/2015
Delta tocopherol	6,1	± 1,0		mg/100 g	2,0		07(S124) rev2 2012 - HPLC	09/06/2015
Gamma tocopherol	87,5	± 10,5		mg/100 g	2,0		07(S124) rev2 2012 - HPLC	09/06/2015
Alpha tocotrienol	< LQ			mg/100 g	2,0		* TOCOFE-OLI - HPLC	09/06/2015
Vitamina E (tocoferolo equivalenti) [403]	8,8			mg/100 g			* TOCOFE-OLI - HPLC	09/06/2015
Vitamina E (UI) [428]	13,0			UI/100 g			* TOCOFE-OLI - HPLC	09/06/2015
POLYCHLORODIBENZODIOXINS AND POLYCHLORODIBENZOFURANES (values referred to the whole product)								
2,3,7,8-TCDD	< LQ			pg/g	0,050		EPA 1613B 1994	11/06/2015
1,2,3,7,8-PeCDD	< LQ			pg/g	0,050		EPA 1613B 1994	11/06/2015
1,2,3,4,7,8-HxCDD	< LQ			pg/g	0,100		EPA 1613B 1994	11/06/2015
1,2,3,6,7,8-HxCDD	< LQ			pg/g	0,100		EPA 1613B 1994	11/06/2015
1,2,3,7,8,9-HxCDD	< LQ			pg/g	0,100		EPA 1613B 1994	11/06/2015
1,2,3,4,6,7,8-HpCDD	< LQ			pg/g	0,150		EPA 1613B 1994	11/06/2015
OCDD	< LQ			pg/g	0,200		EPA 1613B 1994	11/06/2015
2,3,7,8-TCDF	< LQ			pg/g	0,050		EPA 1613B 1994	11/06/2015
1,2,3,7,8-PeCDF	< LQ			pg/g	0,050		EPA 1613B 1994	11/06/2015
2,3,4,7,8-PeCDF	< LQ			pg/g	0,076		EPA 1613B 1994	11/06/2015
1,2,3,4,7,8-HxCDF	< LQ			pg/g	0,100		EPA 1613B 1994	11/06/2015
1,2,3,6,7,8-HxCDF	< LQ			pg/g	0,100		EPA 1613B 1994	11/06/2015
2,3,4,6,7,8-HxCDF	< LQ			pg/g	0,100		EPA 1613B 1994	11/06/2015
1,2,3,7,8,9-HxCDF	< LQ			pg/g	0,100		EPA 1613B 1994	11/06/2015
1,2,3,4,6,7,8-HpCDF	< LQ			pg/g	0,150		EPA 1613B 1994	11/06/2015
1,2,3,4,7,8,9-HpCDF	< LQ			pg/g	0,150		EPA 1613B 1994	11/06/2015
OCDF	< LQ			pg/g	0,200		EPA 1613B 1994	11/06/2015
Total WHO-PCDD/F-TEQ on the whole product (upper bound) *- Limite (Reg. CEE 1881/2006 e s.m.i.) 0,75*	0,204	± 0,029		pg/g			EPA 1613B 1994	11/06/2015
AFLATOXINS B1, B2, G1, G2								
Aflatoxin B1	< LQ			µg/kg	0,050		* MICO-LCMS 2015 Rev.1 - HPLC	05/06/2015
Aflatoxin B2	< LQ			µg/kg	0,050		* MICO-LCMS 2015 Rev.1 - HPLC	05/06/2015
Aflatoxin G1	< LQ			µg/kg	0,050		* MICO-LCMS 2015 Rev.1 - HPLC	05/06/2015
Aflatoxin G2	< LQ			µg/kg	0,050		* MICO-LCMS 2015 Rev.1 - HPLC	05/06/2015
Ochratoxin A	< LQ			µg/kg	0,10		* MICO-LCMS 2015 Rev.1 - HPLC	05/06/2015
MICROBIOLOGICAL RESEARCH								
Aerobic total count in P.C.A. at 30°C for 72 h	< LQ			UFC/ml	1		* 06(S24) Rev.13 2012 - inclusione	08/06/2015
MICROBIOLOGY - MOULDS and YEASTS								

Continued...

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Modena (Italy), li 16/06/2015

Analysis beginning date
29/05/2015

TEST REPORT nr. 15E16625-In-0

SAMPLE **15E16625**

ANALYSIS DESCRIPTION	RESULT	U	REC. %	UNIT OF MEASURE	LQ	LD	METHOD	ANALYSES ENDING DATE
Moulds	< LQ			UFC/ml	1		* 06(S36) rev. 13 2011	08/06/2015

END TEST REPORT

The original document is a PDF file with Digital Signature: 15E16625-In-0-DigitalSignature.pdf

Notes and method reference:
< LQ: = lower than Quantification Limit. Please note that results expressed as '<LQ' may not indicate the absence of the searched parameters in the sample.
[AE]: Analysis performed by a specialized external laboratory
[403]: Fattori utilizzati per il calcolo degli d-alfa-TEs negli oli vegetali : d-alfa-tocoferolo 1,0 dl-alfa-tocoferolo acetato 0,671 beta-tocoferolo 0,5 gamma-tocoferolo 0,1 alfa-tocotrienolo 0,3
[428]: Vitamina E in unità internazionali (UI) = alfa -tocoferolo equivalenti (a-TEs) x 1,49
U: the reported uncertainty is the expanded uncertainty calculated using a coverage factor equal to 2 which gives a reliability of approximately 95%. For microbiological detections it is reported either the lower and the upper bounds of the confidence interval with a probability of 95% K=2 or the confidence interval itself.
Results coming from microbiological tests are calculated according to the Standard ISO 7218:2007/Amd 1:2013. If the results are reported as <4 (CFU/ml) or <40 (CFU/g), this means that the microorganisms are present in the sample but in amounts less than 4 CFU/ml or 40 CFU/g respectively.
LQ: Quantification Limit. It is the lowest analyte concentration which can be detected at an acceptable precision (repeatability) and accuracy, under well defined conditions.
LD: Detection Limit. It is the lowest analyte concentration which can be detected but not necessarily quantified, under well defined conditions.
Conformity evaluation: values not complying with laws, decrees, national and EU regulations or specifications supplied by the customer are evaluated case by case, also taking into consideration the uncertainty of measure for each single test and the regulations on rounding-off of values, and pointed out when considered as "non conform".
Rec %: Recovery % "+" means that the recovery has been applied to the result. The numeric results between brackets (..) after the espression <LQ are purely indicative of traces that cannot be exactly quantified.
Methods marked with an asterisk (*) are not accredited by ACCREDIA (UNI CEI EN ISO/IEC 17025)

TEST REPORT VALID FOR ALL LEGAL PURPOSES (Italian R.D. 1-3-1928 n°842 (article 16), – Italian Law 19-7-1957 n°679 articles 16 and 18, Italian Ministerial Decree 25-3-1986).
Test Report issued according to the 17025:2005 Standard
DATA and SAMPLE STORAGE: Raw data, chromatographic paths and instrumental reports are stored for 5 years. One control sample is stored for 2 months.
Data expressed in this test report refer only to the sample tested in the laboratory. The description or any other reference concerning the sample are declared by the customer. This Test Report cannot be reproduced except in full. Partial reproductions must be authorized in writing by our laboratory.

LABORATORY MANAGER: DR. GIAN CARLO GATTI - MEMBER OF AOAC N. VM 90231001 - EURCHEM

Approved by Analysis Manager - laboratory LMIB: Nicoletta Belletti, Tecnologo degli Alimenti N°208
Approved by Analysis Manager - laboratory LMAA-Nut
Approved by Analysis Manager - laboratory LMAA-Met
Approved by Analysis Manager - laboratory DOX
Approved by Analysis Manager - laboratory LC-MIC
Approved by Analysis Manager - laboratory GC-BRO
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Laboratorio Qualificato D.M. 26-2-87 Art. 4 - Legge 46/82 per la Ricerca Applicata e Innovazione Tecnologica.
Regione Emilia Romagna - AUTORIZZAZIONE Autocontrollo N° 008/MO/008
BNN-Monitoring Fruit and Vegetables Approved Laboratory
I-Monitoring EDEKA AG Fruit and Vegetables Registered Laboratory

Appendix B

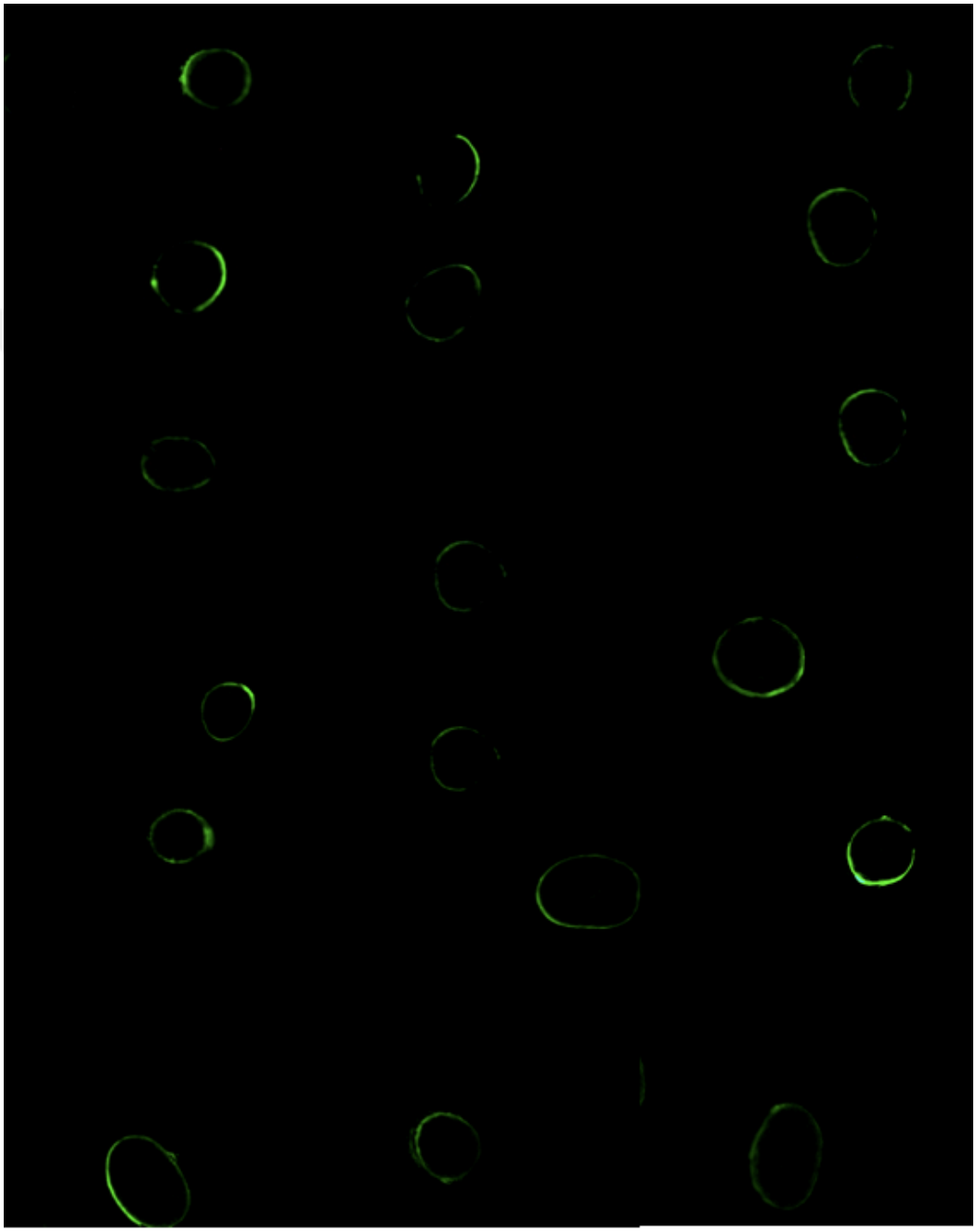


Figure 7-1 Cross sections of virgin hair treated with mineral oil under fluorescence microscopy

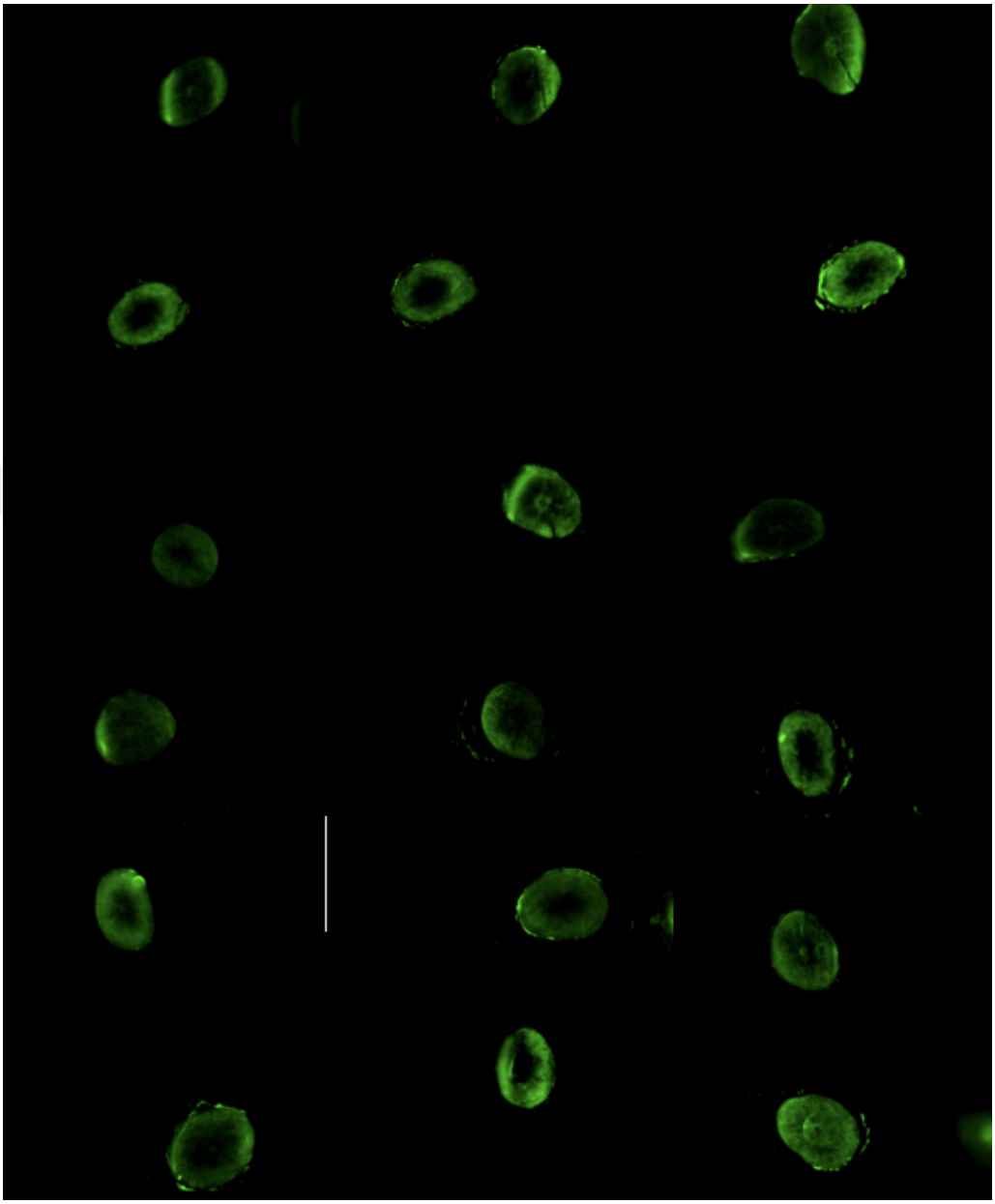


Figure 7-2 Cross sections of bleached once hair treated with mineral oil under fluorescence microscopy

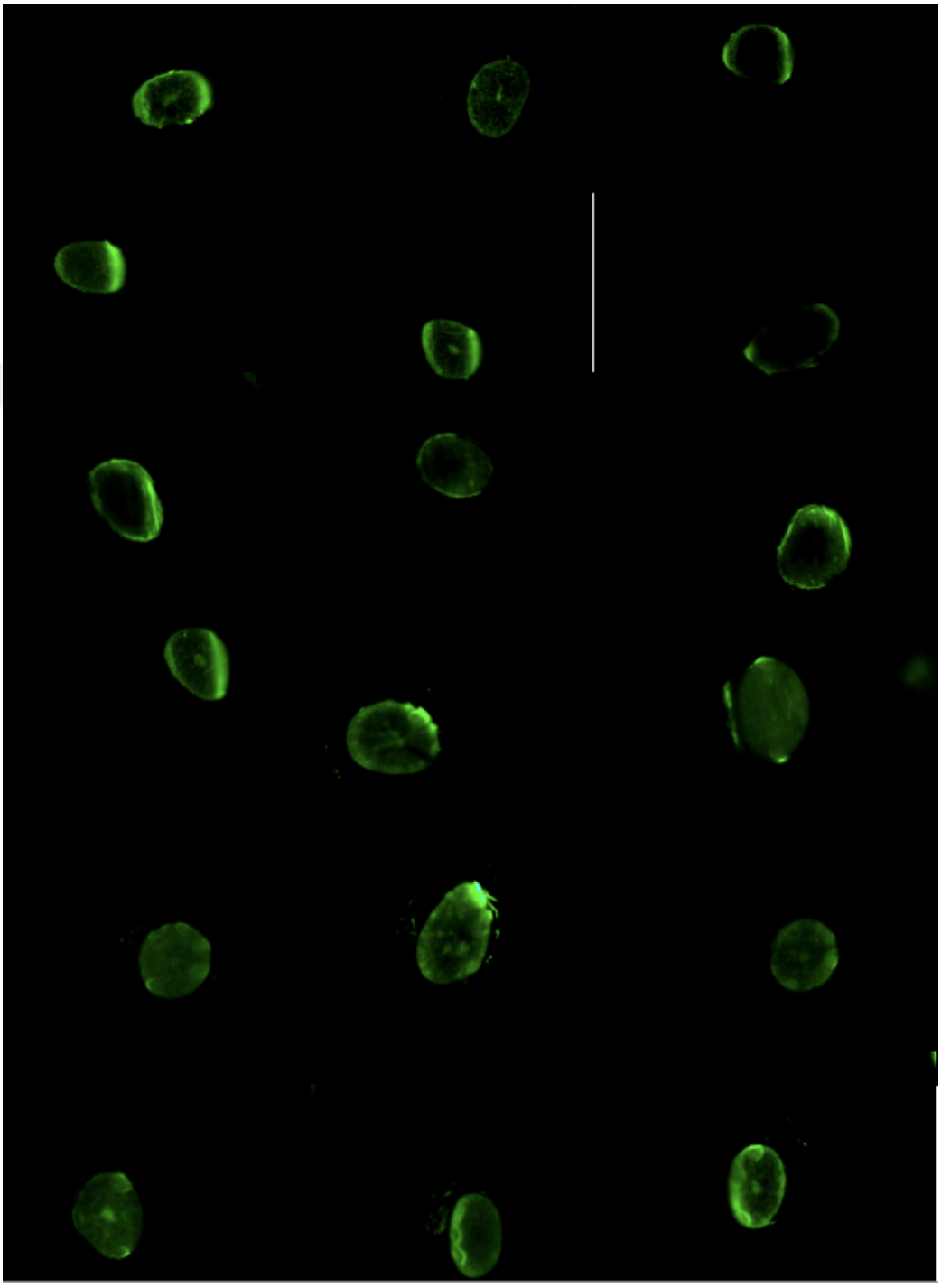


Figure 7-3 Cross sections of bleached x7 hair treated with mineral oil under fluorescence microscopy

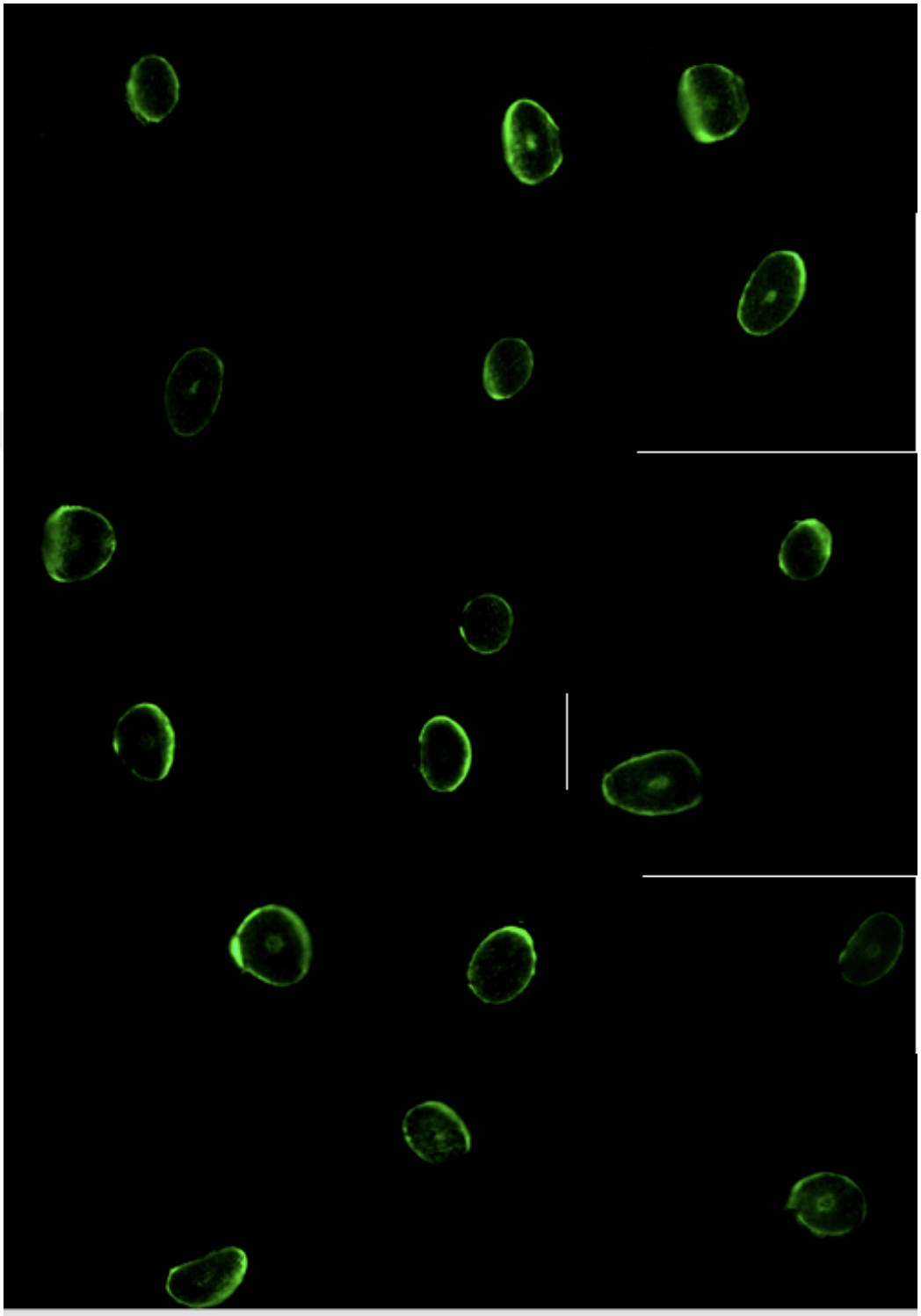


Figure 7-4 Cross sections of virgin hair treated with coconut oil under fluorescence microscopy

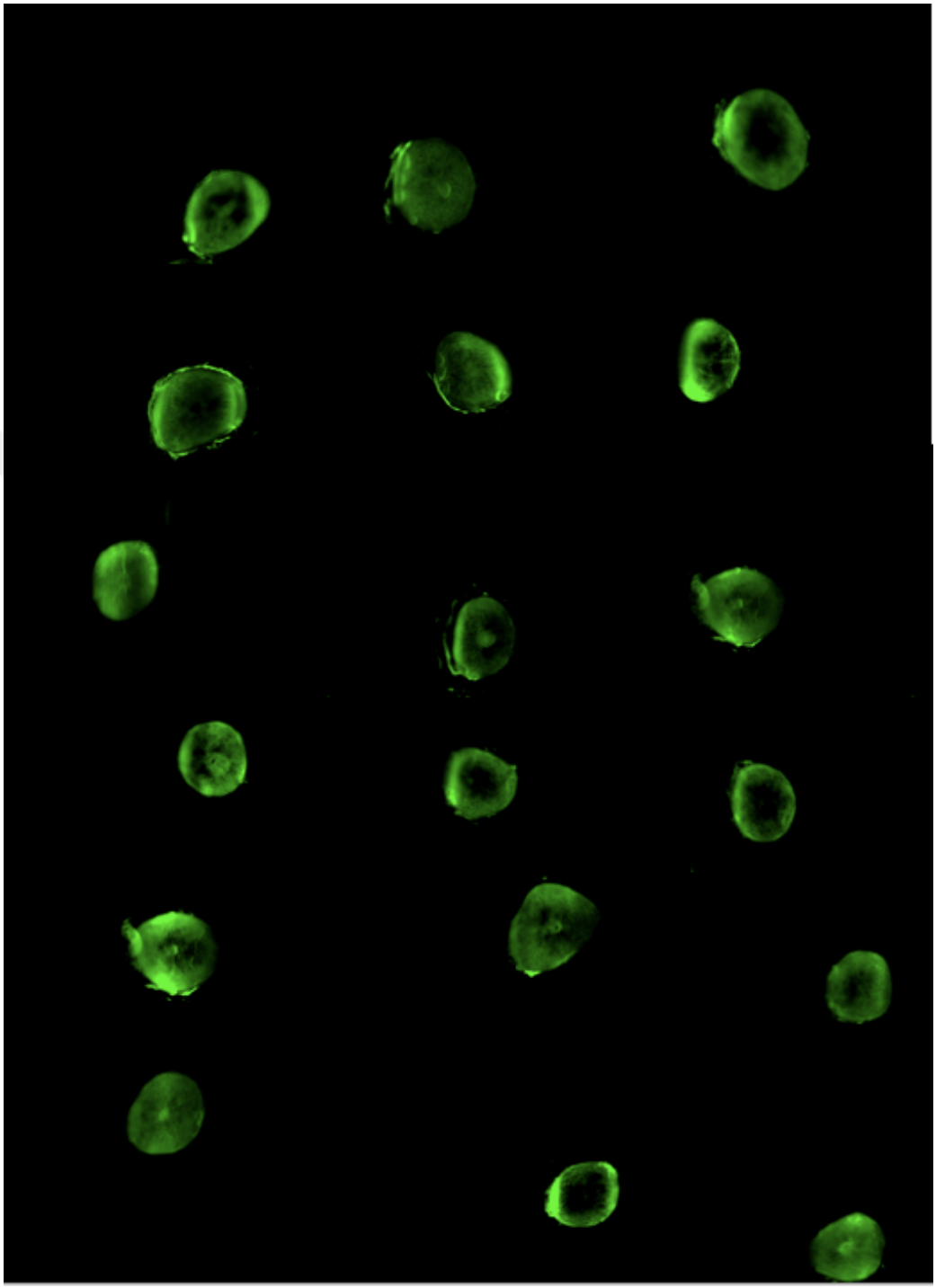


Figure 7-5 Cross sections of bleached once hair treated with coconut oil under fluorescence microscopy

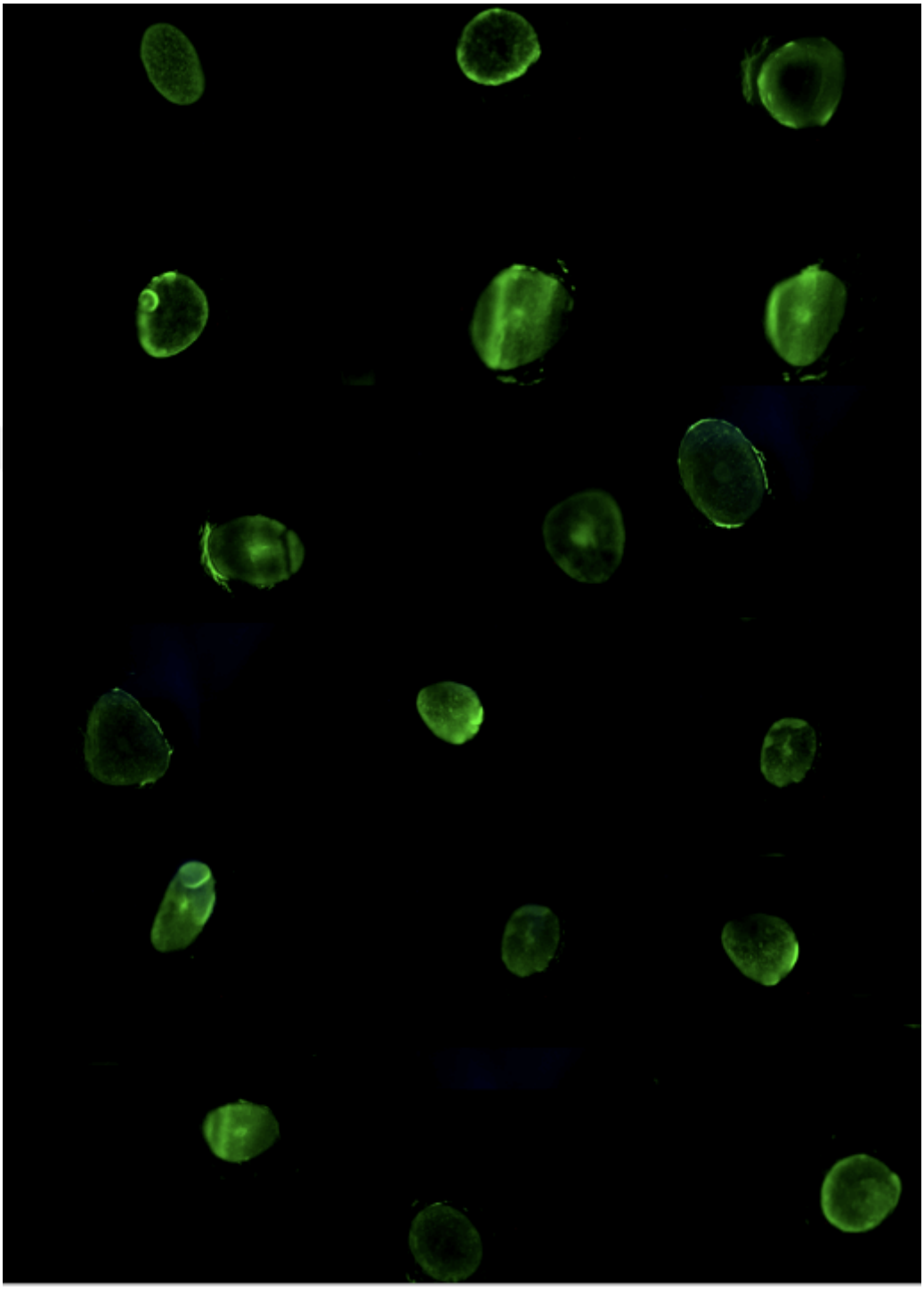


Figure 7-6 Cross sections of bleached x7 hair treated with coconut oil under fluorescence microscopy

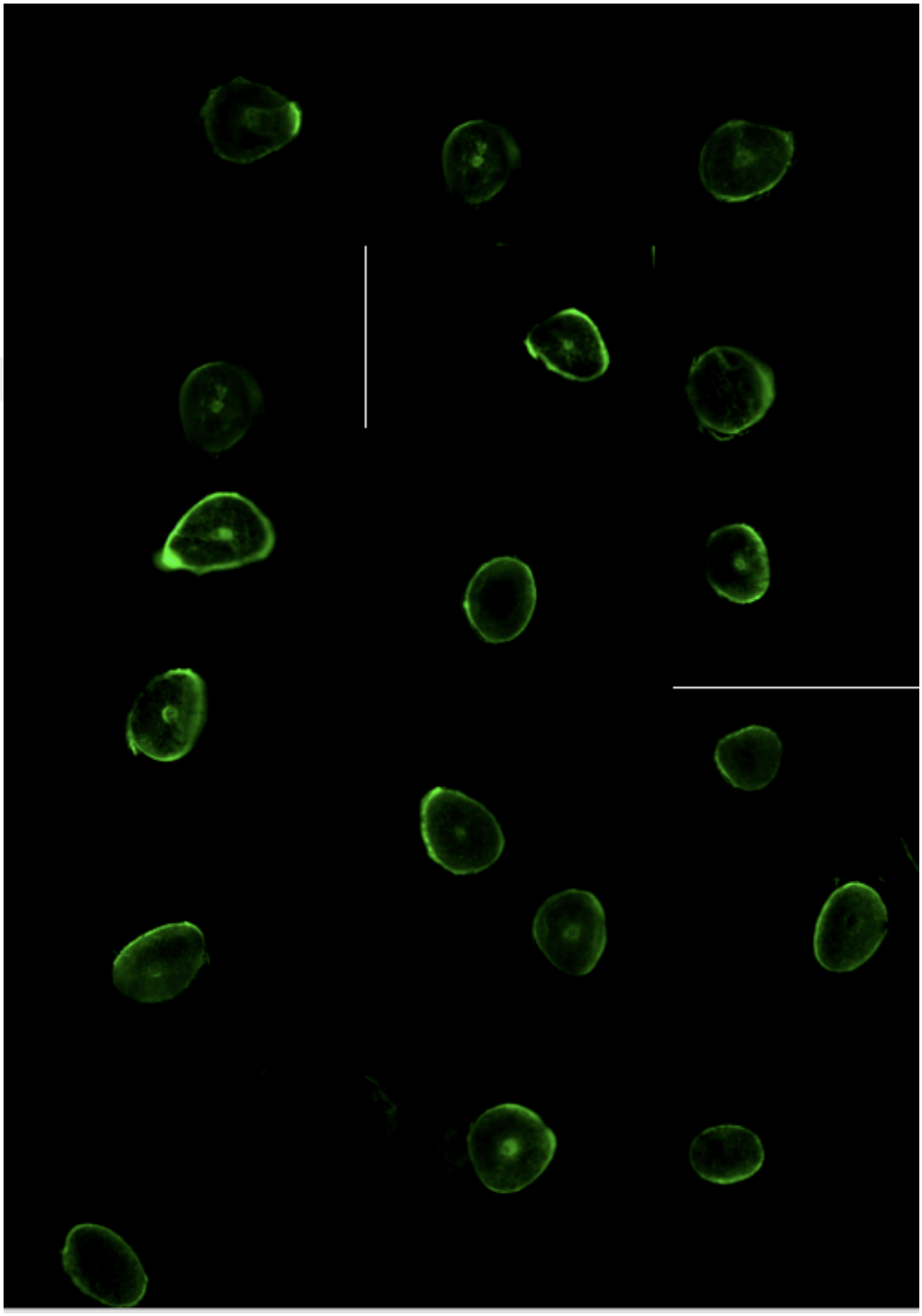


Figure 7-7 Cross sections of virgin hair treated with linseed oil under fluorescence microscopy

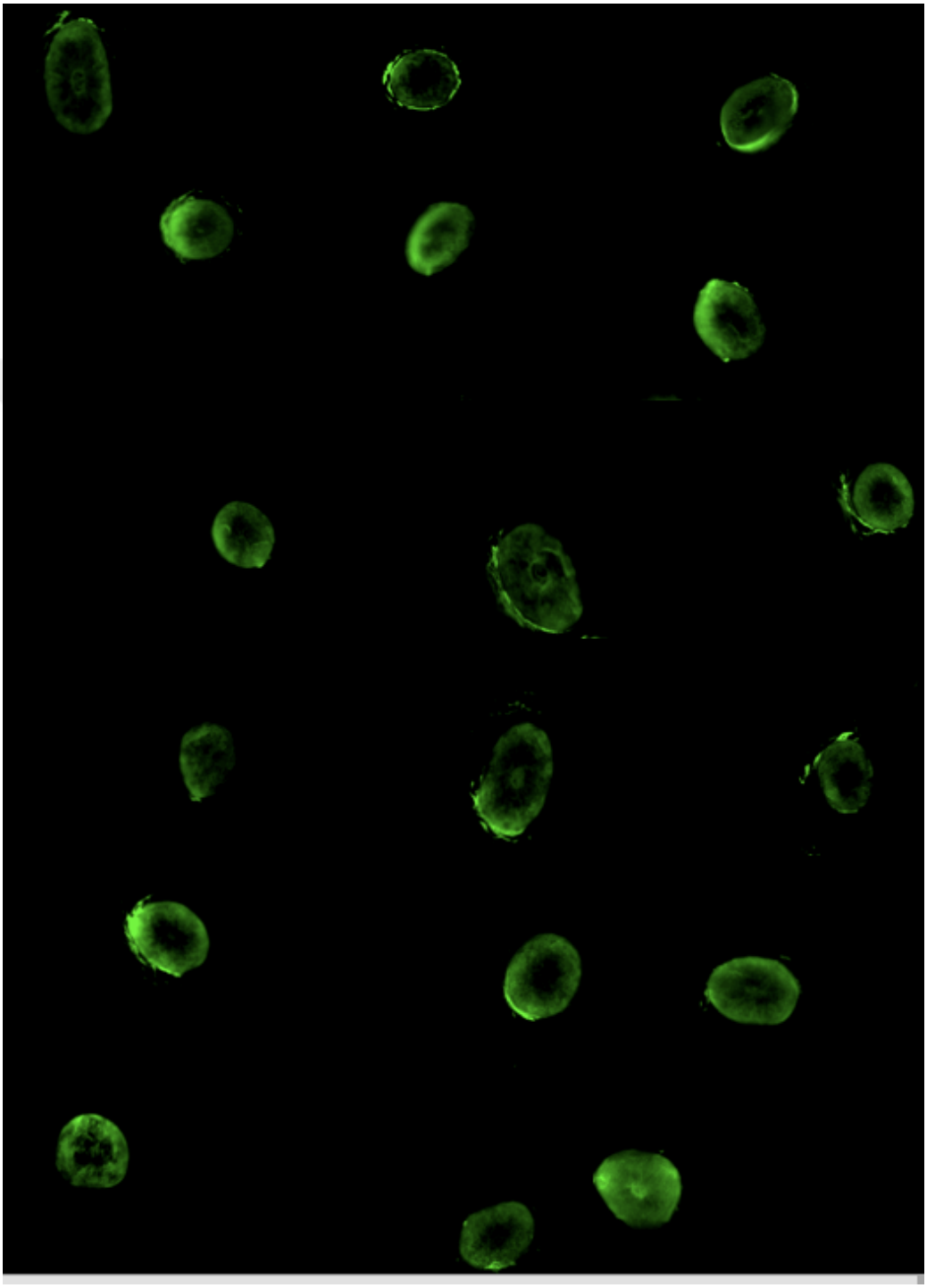


Figure 7-8 Cross sections of bleached once hair treated with linseed oil under fluorescence microscopy

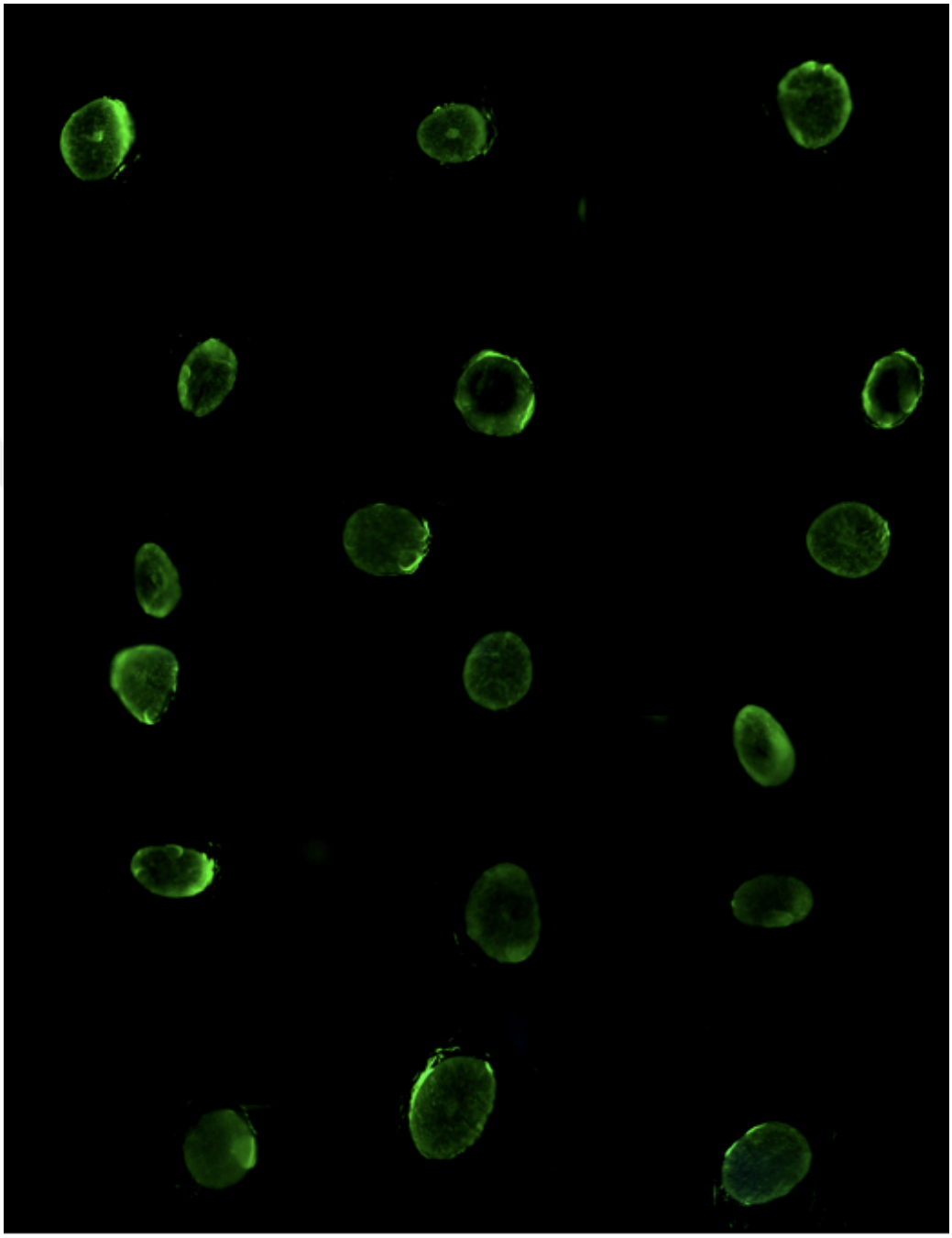


Figure 7-9 Cross sections of bleached x7 hair treated with linseed oil under fluorescence microscopy

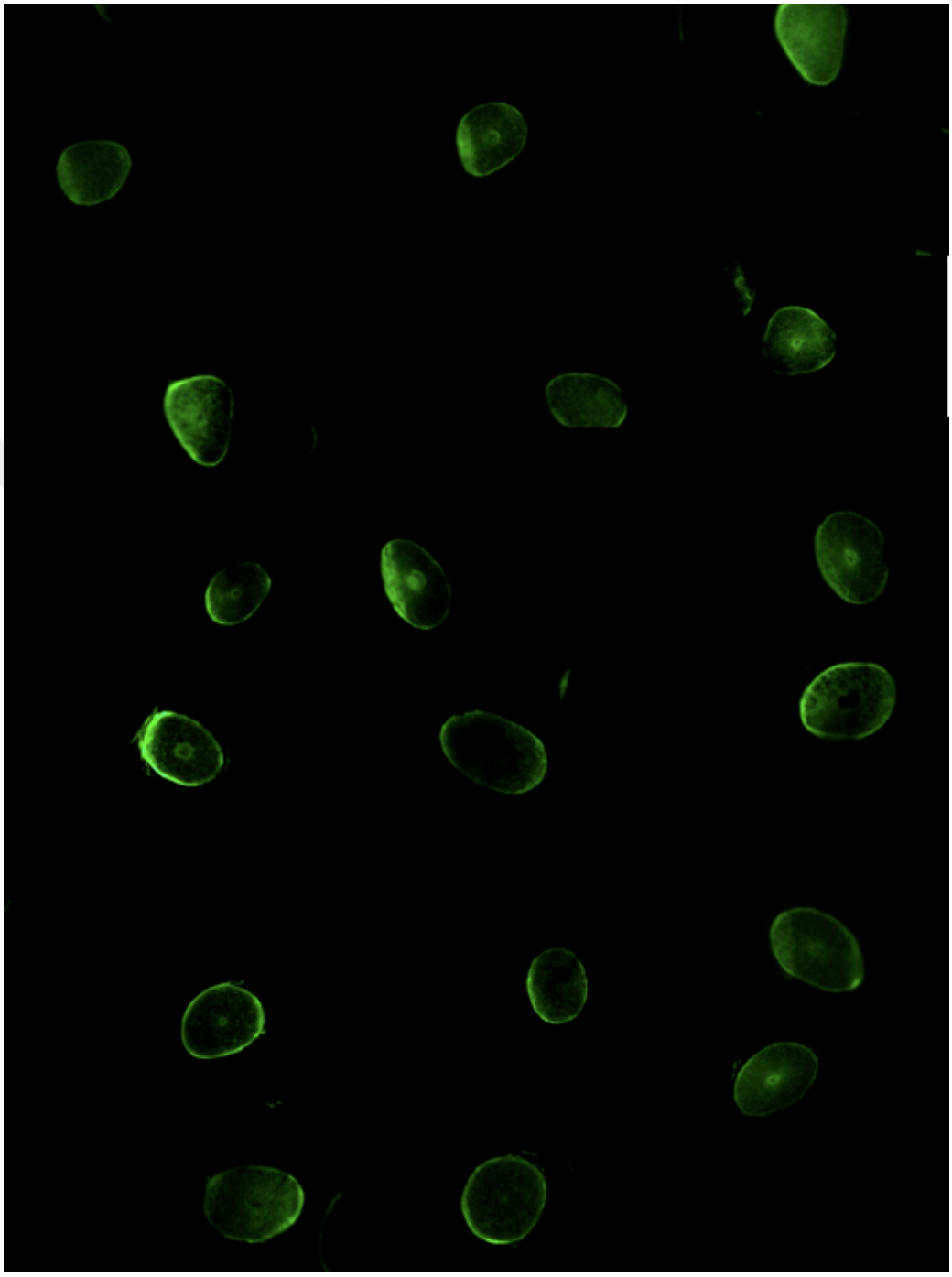


Figure 7-10 Cross sections of virgin hair treated with almond oil under fluorescence microscopy

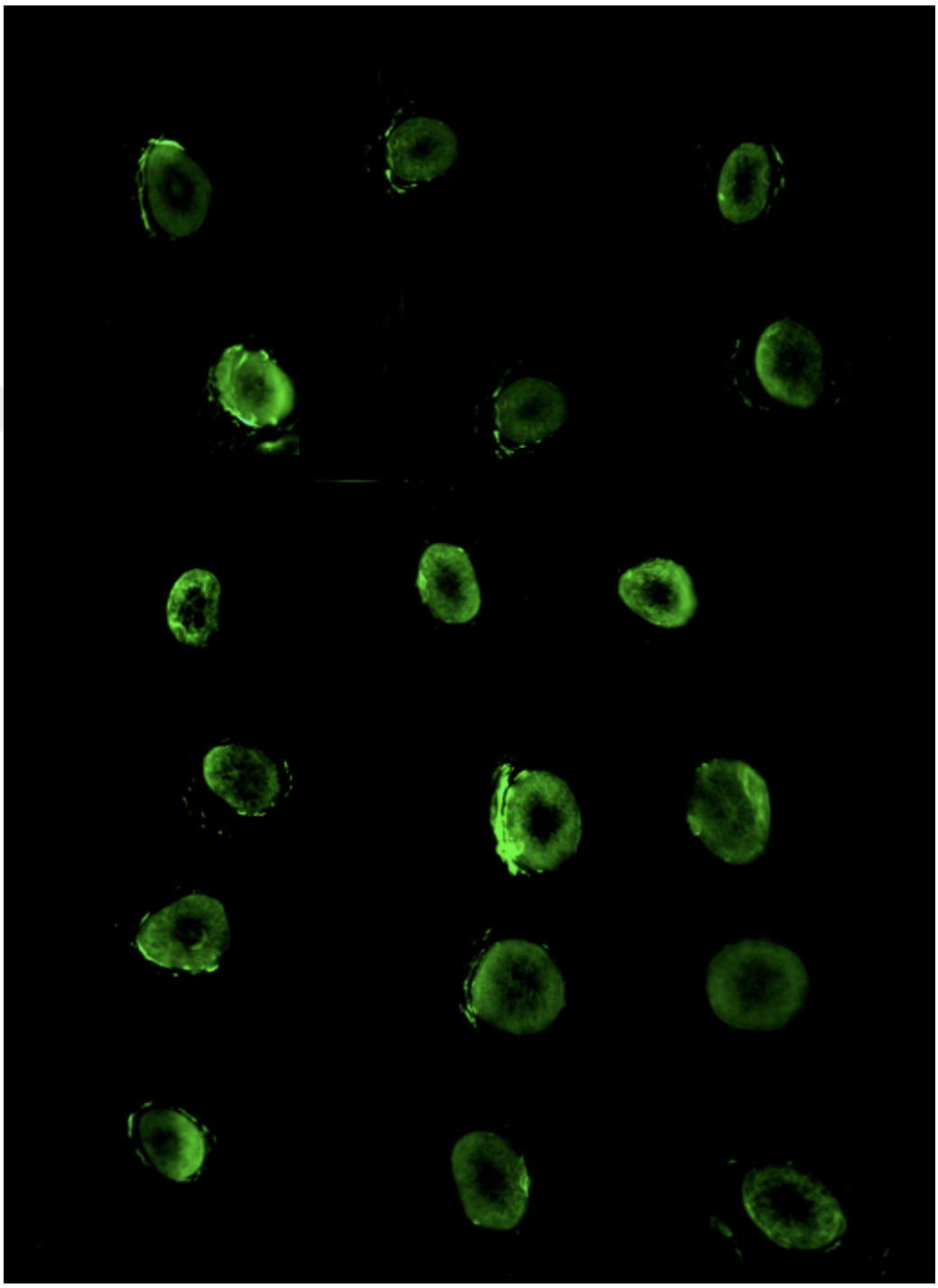


Figure 7-11 Cross sections of bleached once hair treated with almond oil under fluorescence microscopy

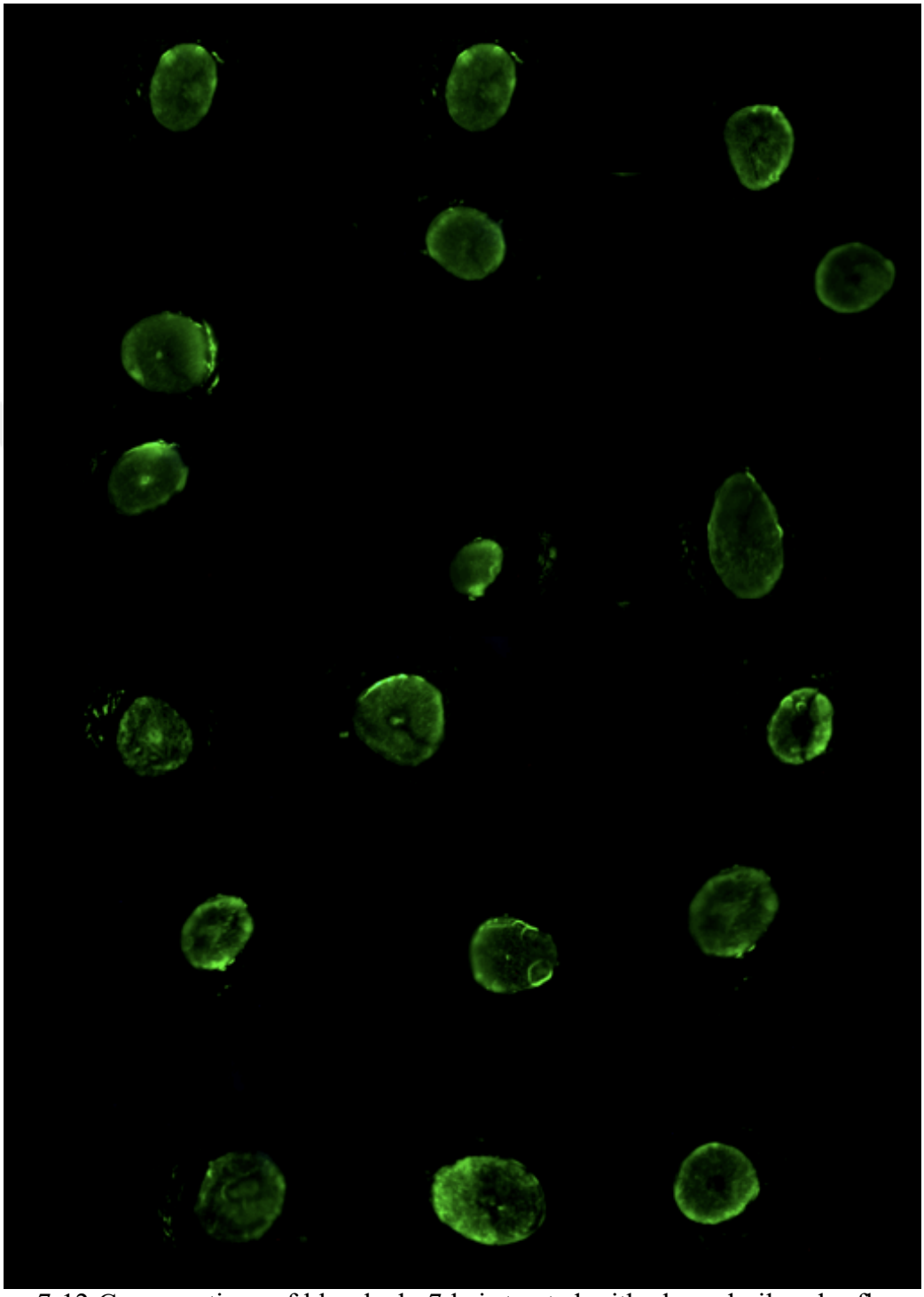


Figure 7-12 Cross sections of bleached x7 hair treated with almond oil under fluorescence microscopy

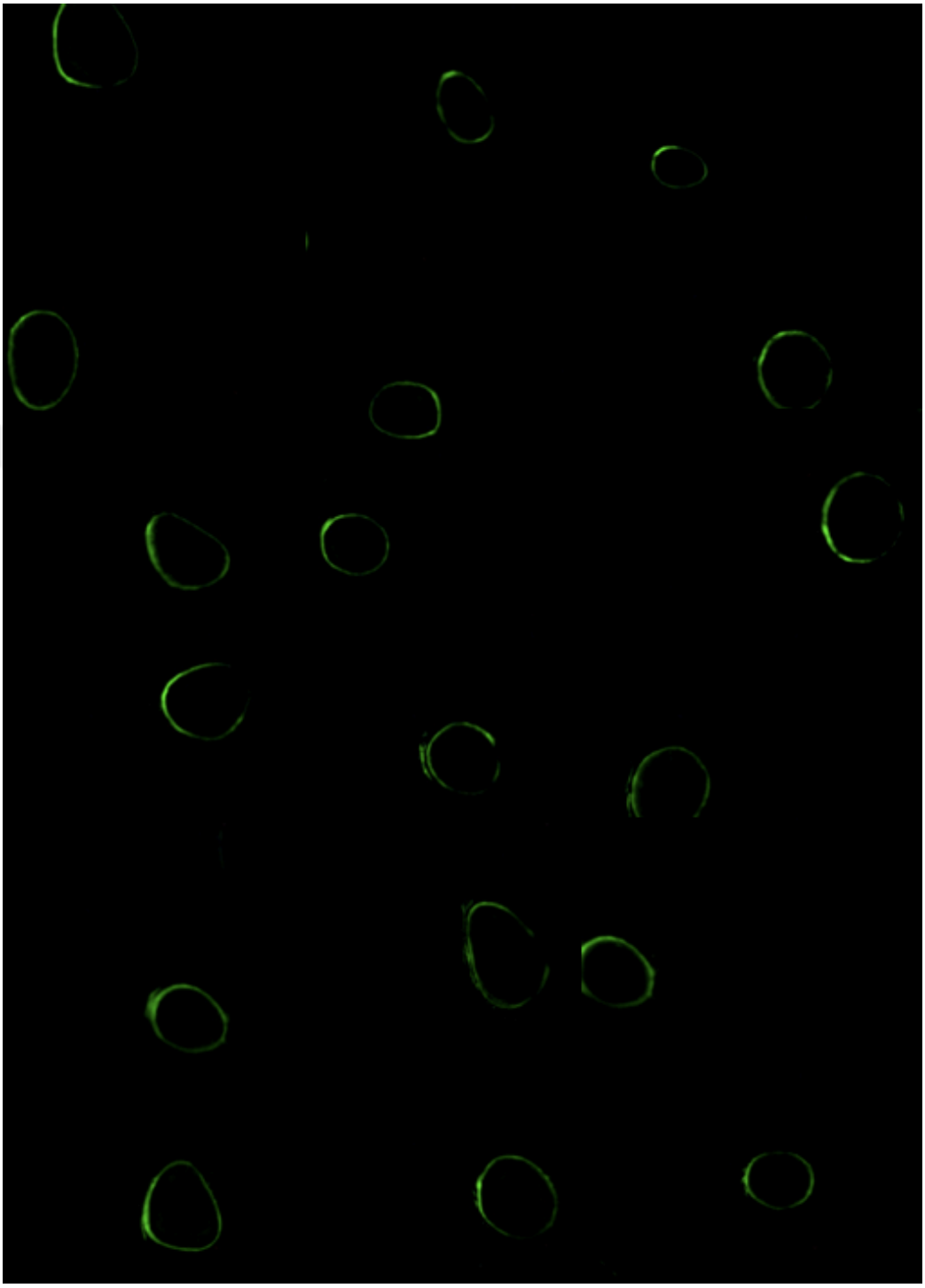


Figure 7-13 Cross sections of virgin hair treated with baobab oil under fluorescence microscopy

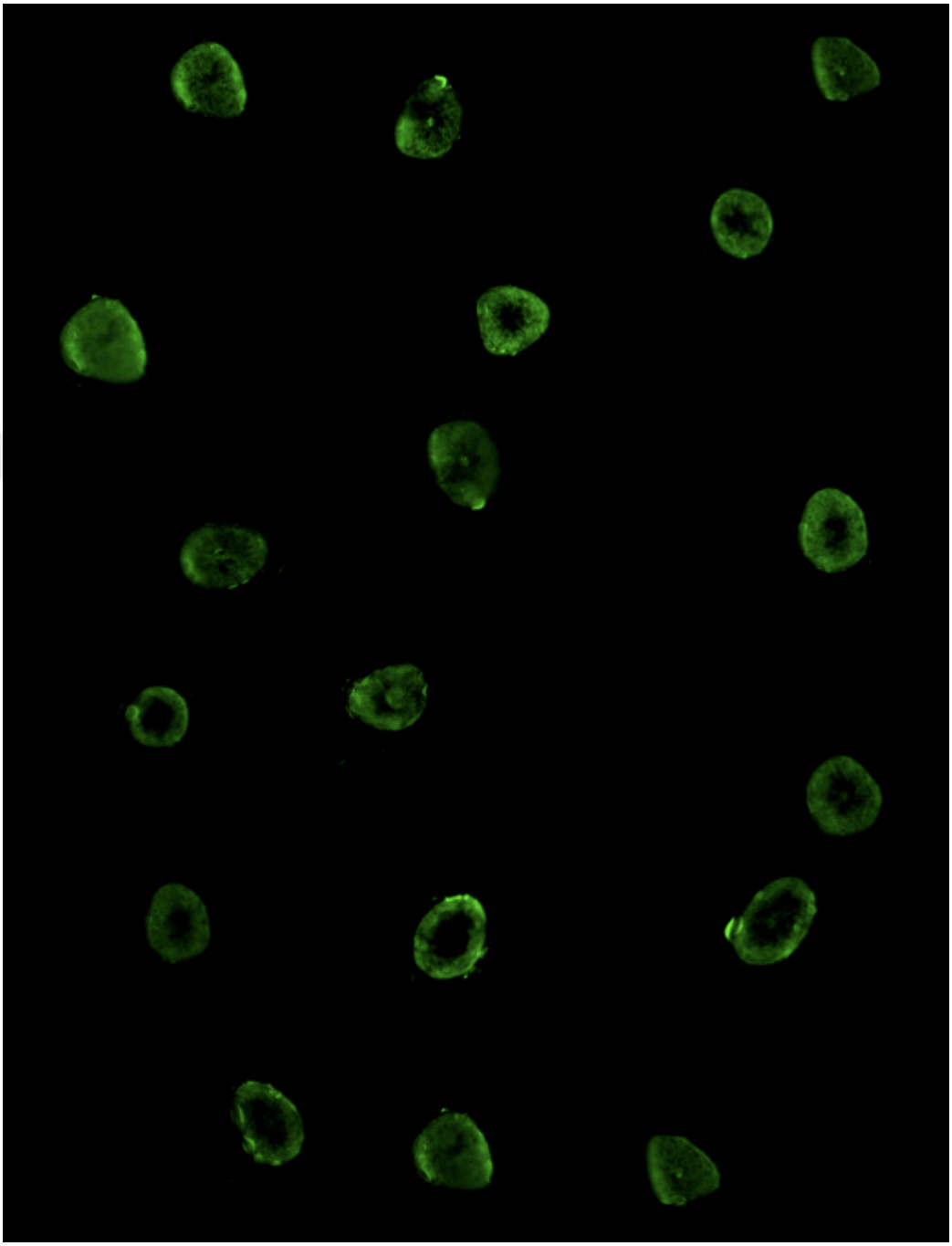


Figure 7-14 Cross sections of bleached once hair treated with baobab oil under fluorescence microscopy

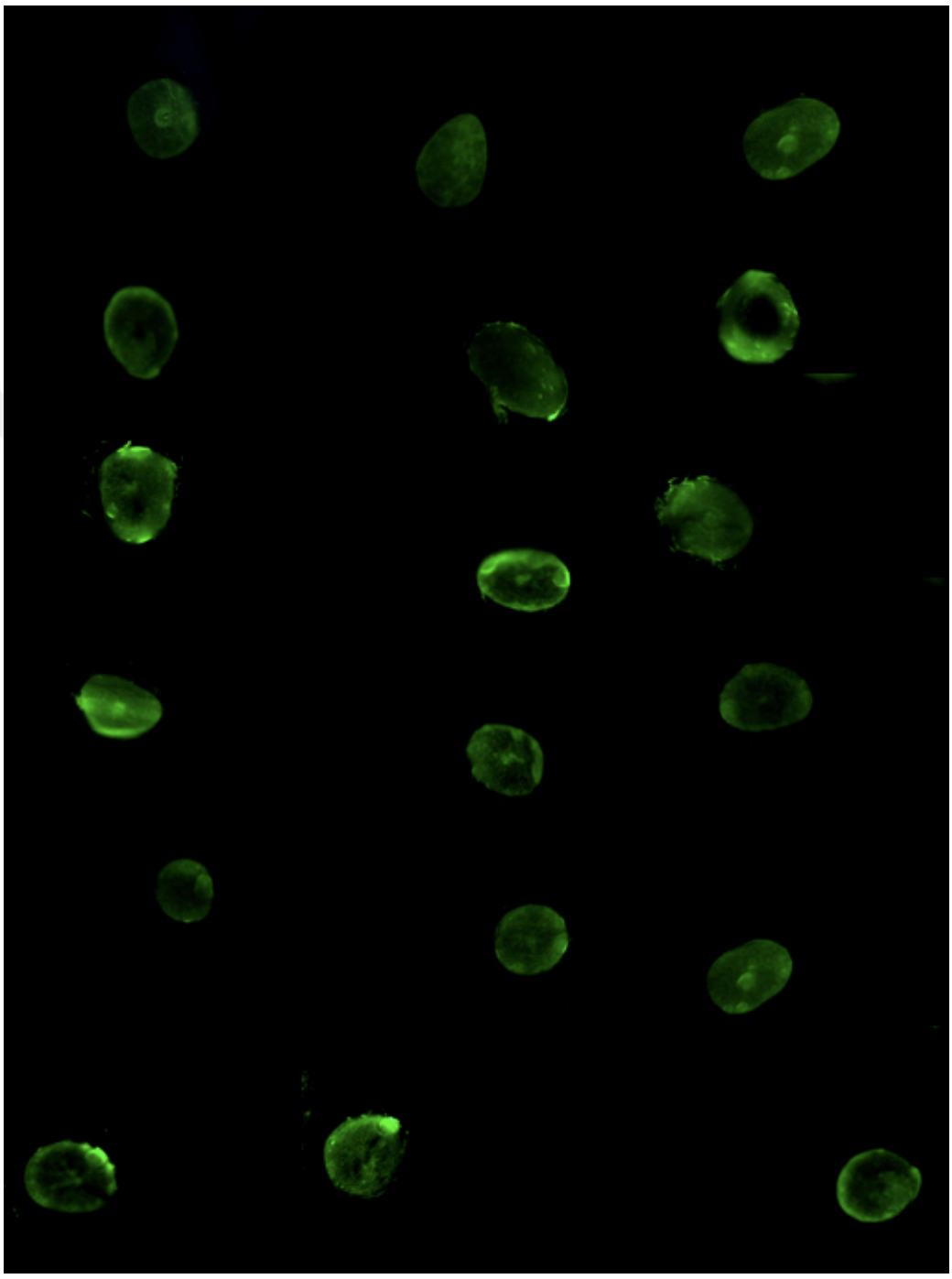


Figure 7-15 Cross sections of bleached x7 hair treated with baobab oil under fluorescence microscopy

Appendix C1.1

3. ULUSLARARASI İLAÇ VE ECZACILIK KONGRESİ
3rd International Convention of Pharmaceuticals and Pharmacies
26-29 NİSAN APRIL 2017 İSTANBUL

P-0726

The Effects of Some Natural Oils on Damaged Hair

Essam Turkmani, Yasemin Uzuner

Department of Cosmetology, Faculty of Pharmacy, Yeditepe University, Istanbul, Turkey

Background: Hair is a fundamental component of human appearance with substantial social and psychological effects during daily life [1]. Achieving a healthy good looking hair is of much importance to many people who had their hair damaged due to several causes starting with daily processes as repeated shampooing, everyday grooming processes, and sun exposure throughout hair chemical treatments like permanent waving which all could somehow lead to a noticeable hair damage [2]. Along with the previously mentioned processes, treating hair fibers with alkaline hydrogen peroxide for the purpose of hair bleaching has increased the probability of detaching hair cuticle layers and even damaging the cortex by forming holes in it [3].

The use of natural oils for hair care is an ancient tradition in many countries and cultures. Coconut oil for example, had been used to achieve a good looking healthy long hair. Nowadays, lots of oils are being extensively used as cosmetic treatments for hair either as a pre-wash or by including in commercial hair care products [4].

Objective: In this study, we investigated the damage caused to hair due to bleaching, and explored the benefits of applying coconut oil and linseed oil to damaged hair.

Methods: Hair tresses were bleached five times following the same protocol each time. Virgin and bleached hair tresses were cleaned using base shampoo and left to dry overnight. Hair was then stored at a temperature of 20° C (±2°) and a relative humidity of 45% (±5%). Tresses were divided into the following test groups: (a) virgin hair, (b) bleached hair, (c) bleached hair treated with oils. Virgin hair was used as a reference and oils were only applied to bleached hair tresses to evaluate the benefits of using the oils by comparing the results of the tests before and after oil application. Bleached tress 1 was treated with coconut oil, whereas bleached tress 2 was treated with linseed oil.

The following tests were conducted for all studied hair groups: scanning electron microscopy (SEM), tensile strength, combing forces, and hair breakage due to repeated combing.

Results: SEM images showed significant damage in the cortical cells of bleached tresses due to the chemical treatment, no improvement was noticed after oils application. Combing forces of oil treated bleached tresses were considerably reduced if compared to bleached tresses before oil application and even to virgin hair. Applying oil to bleached hair notably improved tensile strength results which were best for virgin hair, and worst for bleached hair before oil application. Hair breakage due to repeated combing results also showed improvements after oil application.

Conclusion: As it is well known, our study showed that hair bleaching causes immense damage to the fibers, on the other hand, coconut oil and linseed oil seem to have good effects on damaged hair; these effects might be further studied by using other test techniques and methods.

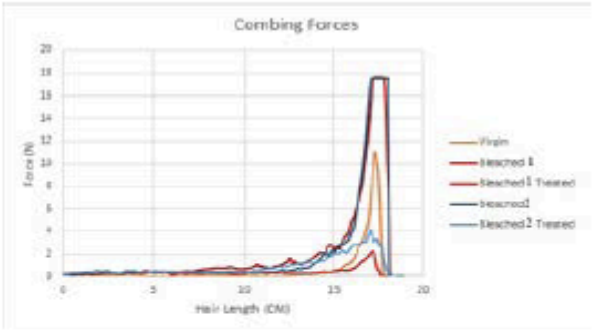
References

[1] Cruz, C., Costa, C., Gomes, A., Matama, T., Cavaco-Paulo, A., *Cosmetics*, 3, 26-47, 2016.
[2] Dias, G., Reis, M.F., *International Journal of Trichology*, 7, 2-15, 2015.
[3] Masukawa, Y., Tsujimura, H., Tanamachi, H., Narita, H., Imokawa, G., *Exog Dermatol*, 3, 273-281, 2004.

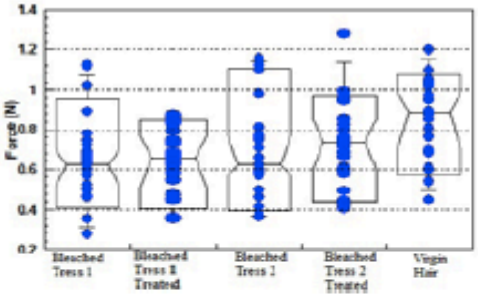
[4] Gode, V., Bhalla, N., Shirhatti, V., Mhaskar, S., Kamath, Y., *Journal of Cosmetic Science*, 63, 27-31, 2012.

Keywords: Hair damage, hair bleaching, coconut oil, linseed oil.

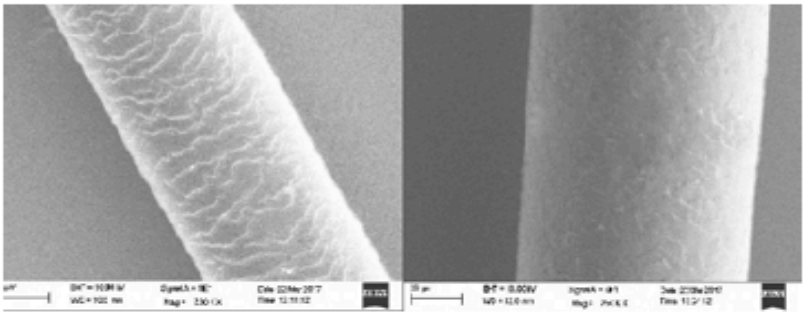
Combing forces for virgin hair, bleached hair, bleached hair treated with oils



Force at break data for virgin hair, bleached hair, and bleached hair treated with oil.



SEM photomicrograph of root section of virgin hair to the left and bleached hair to the right



Appendix C1.2

3. ULUSLARARASI İLAÇ VE ECZACILIK KONGRESİ — 26-29 NİSAN 2017

The Effects of Some Natural Oils on Damaged Hair

Essam Turkmani [1], Yasemin Uzuner [2]

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2-Acibadem University, Faculty of Pharmacy, Kayisdagi Street, 34755 Atasehir, Istanbul, Turkey

INTRODUCTION

Human hair is a highly organized cylindrical appendage that contains keratin and grows from big cavities that extend from the top of the skin into the dermis through the stratum corneum and the epidermis, those large cavities are named hair follicles [1,2] (Figure 1). Secondary components that contribute to the total mass of hair are lipids and melanin pigment [3]. Morphologically, a totally developed hair shaft contains three or occasionally four different structures or units. At the outermost is the cuticle, which is classified to be the protective structure of the hair. This protective layer surrounds the cortex, which contains the main section of the mass of the hair fiber. Near the center of the fiber, coarse hairs generally contain porous region called the medulla. The last important structure is the cell membrane complex (CMC) which is considered to be the glue that holds the cells to each other [2] (Figure 2).

Figure 1: A section of human skin clarifying a hair fiber in its follicle as it emerges through the skin [2].

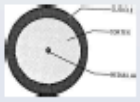

Figure 2: Schematic diagram of a cross section of a human hair fiber [2].

Hair care processes as repeated shampooing, everyday grooming processes, chemical hair treatments like permanent waving and hair bleaching, all can somehow lead to a noticeable hair damage [4].
The use of natural oils for hair care is an ancient tradition in many countries and cultures. Coconut oil for example, had been used to achieve a good looking healthy long hair. Nowadays, lots of oils are being extensively used as cosmetic treatments for hair either as a prewash or by including in commercial hair care products [5].

OBJECTIVE

In this study, we investigated the damage caused to hair due to bleaching, and explored the benefits of a single use of coconut oil and linseed oil to damaged hair.

MATERIALS & METHODS

Hair switches used were a gift from Unilever (purchased from International Hair Importers & Products, NJ, USA).
Hair was bleached five consecutive times for 30 minutes each time following exactly the same protocol. Bleaching powder and oxidant cream used for bleaching were purchased from a local store. Bleached and virgin hair tresses were then washed with base shampoo prepared in our lab (Table 1), and left to dry overnight. Hair was then stored at a temperature of 20° C (±2) and a relative humidity of 45% (±5).

Material	Function	(%)
Texapon	Primary surfactant	12.00
Cocoamidopropyl Betaine Tegobetain	Co-surfactant	1.60
DMDM Hydantoin Glydant	Preservative	0.40
Sodium Chloride	Thickener	1.40
Distilled Water		to 100%

Table 1: Base shampoo formulation

Coconut oil and linseed oil used were commercially available. An amount of 0,01g oil per 1g hair was applied to each side of the studied hair tresses. Oil was gently massaged on the hair for 30 seconds and hair was then combed x10 using the wide teeth of a Hercules No. 366 comb to ensure even spread of the oil along the hair switch.

Tresses were divided into the following test groups: (a) virgin hair, (b) bleached hair, (c) bleached hair treated with oils. Virgin hair was used as a reference and oils were only applied to bleached hair tresses to evaluate the benefits of using the oils by comparing the results of the tests before and after oil application.
Scanning electron microscopy was used to evaluate the damage caused to hair after bleaching. For that purpose, hair samples of virgin and bleached hair were coated with a carbon/gold film in order to lead electric current using Baltec SCD 005 Sputter Coater (BAL-TEC GmbH, Germany) for 40 seconds (figure 3). Scanning electron microscopy was then performed using a ZEISS EVO 40XVP SEM (Carl ZEISS AG, Germany) at a magnification of x2500 (figure 4).

Figure 3: Baltec SCD 005 Sputter Coater

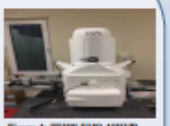

Figure 4: ZEISS EVO 40XVP SEM

Tensile strength and combing forces were measured using a device specifically built for this purpose and equiped with an 18 newton force sensitive cell running at a constant speed of ~ 0.35 cm/sec as shown in (figures 5 and 6). For tensile srength, 25 hair fibers of each previously mentioned test groups were used. For combing forces, Hercules NO 366 wide teeth comb was used. Hair tresses were combed twice prior to measuring to remove severe tangling.

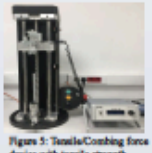

Figure 5: Tensile/Combing force device with tensile strength attachments.

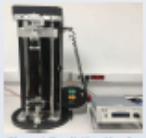

Figure 6: Tensile/Combing force device with combing force attachments.

RESULTS

Scanning Electron Microscopy

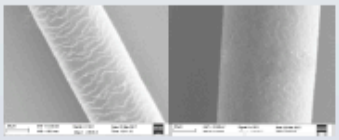

Figure 7: Side by side SEM photomicrographs of root-section of virgin hair to the left and bleached hair to the right

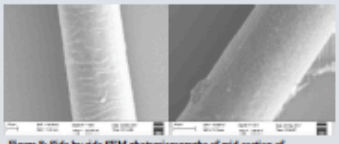

Figure 8: Side by side SEM photomicrographs of mid-section of virgin hair to the left and bleached hair to the right

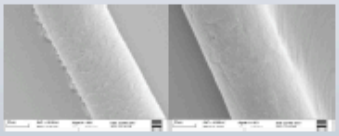

Figure 9: Side by side SEM photomicrographs of tip-section of virgin hair to the left and bleached hair to the right

Tensile Strength

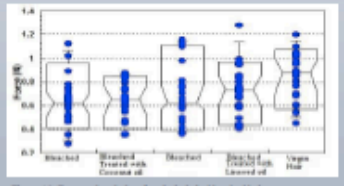

Figure 10: Force at break data for virgin hair, bleached hair, and bleached hair treated with oils.

Combing Forces

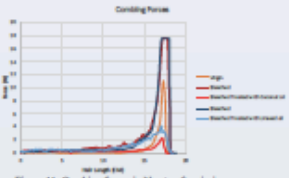

Figure 11: Combing forces in Newton for virgin hair, bleached hair, bleached hair treated with oils

DISCUSSION

Figures 7-8-9 of the virgin hair shows a slight degradation in the status of the cuticle from the root section towards tip end through the mid-section which is normal due to hair aging and as a result of the exposure of the sections away from the root to more natural and mechanical factors like sunlight, hair combing, hair dryer, and other factors. On the other hand, bleached hair parts of the figures show excessive damage caused to hair after bleaching in all hair sections, and as figure 9 shows, parts of the cuticle were even diminished. Chemical bleaching deteriorate the cell membrane complex by oxidizing thioester links between cuticle cells. It also oxidizes cystine residues of the matrix in the cortex and other hair regions as A-layer and exocuticle within cuticle cells. These processes leads to break down of the cell membrane complex, the cuticle and cortex components and eventually dissolves proteins in these regions.
Figure 10 presents force at break data for all test groups for samples of 25 hair fiber each group. Virgin hair was the strongest among the samples with an average of 0.88 N force at break. Bleached hair on the other hand, had an average of 0.61 N force at break. Applying oils to bleached hair slightly increased the force required to break hair fibers as applying coconut oil increased that force to 0.65 N and linseed oil increased it to 0.72 N. Hair strength, in general, is attributed to the cortex. This can be linked to the fact that coconut oil is well known to penetrate into the hair cortex. Linseed oil, on the other hand, has a noticeable amount of oleic acid (18.51% of total fatty acids) [6], and by that is also likely to penetrate into hair cortex [7].
Both of the oils showed remarkable reduction in the combing forces as figure 11 demonstrates, which is mainly related to the lubricating effects and film forming properties of oils.

CONCLUSION

This study is to be continued to see the effects of these oils, and other oils, on damaged hair using SEM, differential scanning calorimetry and other test techniquesin order to clarify the effects of hair penetrating oils on damaged hair.

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Appendix C2.1

(KS-PS-3)

UYGULANAN KİMYASAL İŞLEMLERİN VE BAKIM ÜRÜNLERİNİN SAÇ ÜZERİNDEKİ ETKİLERİ

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Saçların genel sağlığı ve görüntüsü, gerek sosyal gerek psikolojik etkileri nedeniyle günlük yaşamımızda önemli yer tutar[1]. Tekrarlanan günlük bakım işlemleri (şampuanlama, kurutma) , güneş ışınlarına maruz kalma, saçın rengini değiştirme (boyama, açma), kalıcı şekillendirme (perma, düzleştirme) gibi işlemler saç tellerinin hasarlanmasına yol açabilir[2]. Bu işlemlerin birçoğu saç tellerinin kimyasal ve anatomik yapısını [3] bozar, örneğin alkali işlemler ve oksidasyon gerektiren saç rengini açma (bleaching) işleminin saç tellerinin en dış katmanı olan kütikül tabakasının yerinden kalkmasına yol açtığı, hatta korteks tabakasının yapısını da etkilediği pek çok araştırmacı tarafından bildirilmiştir[4]. Saçların sağlıklı ve güzel görünümlü olmasını sağlamak üzere de, farklı yollarla etki eden sayısız ürün tüketici kullanımına sunulmaktadır. Doğal yağların kullanımı pek çok ülkede geleneksel bir saç bakım yöntemi olarak uzun yıllardır kullanılmaktadır. Hindistan cevizi yağı, zeytinyağı, badem yağı gibi yağlar başta olmak üzere bitkisel kaynaklı pek çok yağ yıpranmış saçların yeniden sağlıklı ve parlak görünmesi için kullanılmaktadır. Son yıllarda artan sayıda yeni doğal yağlar da farklı şekillerde, saç bakım ürünü olarak veya diğer bakım ürünlerinin formüllerinde yer alarak kullanılmaya başlanmıştır4. Bu çalışmanın amacı, saçın rengini açma işleminin saç tellerinin fiziksel ve kimyasal yapısı üzerindeki zararları ve doğal yağların iyileştirici etkilerini araştırmaktır. Kimyasal işleme maruz kalmamış (virgin hair, VH) ve rengi tekrarlanan sayıda kimyasal işlemle açılmış (bleached hair, BH) saç tutamlarının özellikleri incelenerek, renk açma işleminin etkileri incelenmiştir. Aynı saç tutamlarına farklı yağlar uygulanıp bekletildikten sonra, bu özellikleri yeniden incelenmiş ve uygulanan yağların olumlu etkileri olup olmadığı araştırılmıştır. Saç tutamlarının özellikleri elektron mikroskobu (SEM) ile yüzey görüntülerinin incelenmesi, gerilme direnci, ıslak ve kuru tarama direnci ve tekrarlanan taramaya dayanıklılık testleri ile araştırılmış, sonuçlar istatistiksel olarak karşılaştırılarak değerlendirilmiştir. Uygulanan yağların kortekse penetrasyonu ise saç tellerin enine kesitlerinin floresan mikroskop ile görüntülenmesi ve Diferansiyel Taramalı Kalorimetre (DSC) ile soğurulan veya salıverilen enerji miktarının tespiti yöntemleriyle incelenmiş, yağlar uygulanmadan önce ve uygulandıktan sonra elde edilen sonuçlar karşılaştırılmıştır. Alınan sonuçlara göre, kimyasal beyazlatma işleminin yalnız 1 kez uygulanmasının bile kütikül tabakasında önemli hasara yol açtığı yapılan tüm test sonuçlarında olumsuz etkiler olarak görülmüştür. Beyazlatma işleminin 3,5,7 kez tekrarlanması ile olumsuz etkiler artmaktadır. Kullanılan yağların sadece bir kısmı VH tutamlarında korteks içine penetre olurken (Şekil 1a ve b), BH örneklerinin tümünde penetrasyon görülmüştür (Şekil 2a ve b). Renk açma işleminin sadece bir kez uygulanması durumunda bile, saç tellerinin koruyucu katmanı olan kütikülün hasarlanması nedeniyle, tüm yağların kortekse penetrasyonunun mümkün olduğu sonucuna varılmıştır. Saçların gerilme direnci, tarama direnci ve tekrarlanan taramaya dayanıklılık testleri ile testlerde kullanılan yağların penetrasyon özellikleri arasındaki bağıntılar da ayrı ayrı incelenmiştir.

Şekil 1.a. ve 1 b : VH korteks içine penetre olan ve olmayan yağlar

Şekil 2.a. ve b aynı yağların BH korteks tabakasına

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Appendix C2.2

9. KOZMETİK Kimyası, Üretimi ve Standardizasyonu KONGRESİ 22-24 ŞUBAT 2019
www.kozmetikkongresi.org | ANTALYA

Saça Uygulanan Kimyasal İşlemlerin ve Bakım ürünlerinin Etkileri

Essam Turkmani [1], Yasemin Yağan Uzuner [2]
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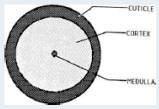
GİRİŞ

İnsan kılları vücudun oldukça geniş bir yüzeyini kaplar [1] ve önemli derecede organize olmuş silindirik bir yapıda , üst derinin eklerinden biridir. Yapısında yüksek oranda keratin bulunur (epidermisin ölü stratum korneum hücreleri) Dermis içine kadar uzanmış olan «kıl folikülü» olarak adlandırılan yapılar içinde değişime uğrayan kıl kökündeki hücrelerin uç uça uzamayı sağlayacak şekilde yapılanmasıyla deri yüzeyine doğru büyür [1,2] (Şekil 1). Keratin dışında kıl lipidleri ve kıllara rengini veren melanin pigmentleri de kıl yapısı içinde önemlidir (3)

Enine kesitinde, saçın iç içe halkalar halinde, farklı yapıları olan tabakalardan oluştuğu görülür (Şekil 2)
1-Kütikül
2-Kortek
3- Medulla , sadece daha kalın saçlarda gözlenir.
Diğer önemli bir yapıda Hücre mem branı kompleksi adı verilen (CMC) ve adeta bir tutkal gibi diğer yapıları yapıştıran diğer bir önemli yapıdır[2].

Şekil 1
Deri ve saç folikülünün deri içinde yerleşimi



Şekil 2
Saç / kıl enine kesiti[2].

Saç boyama ve rengini açma işlemleri

Her iki kimyasal işlemde de saçın oxidasyonu söz konusudur. Yüksek oranda da alkali uygulaması yapılır (4). Özellikle de saç rengini açma saçın yapısını bozmakta , CMC ve kutiküla hücrelerinin tiyo- ester bağları oksitlenmektedir. Bu işlemler sonucunda kütikül tabakası yer yer kalkabilmekte, hatta günlük yıkama, kurutma, tarama gibi bakımlar sırasında korteks tabakasında delikler oluşabilmektedir. Bu tür kimyasal ve günlük bakım işlemleri saçın yapısını değiştirdiği gibi, dokunınca hissedilenler, görünüşü, parlaklığı gibi özelliklerini de büyük ölçüde etkilemektedir [4-5].

Doğal Yağların kullanımı

Uzun yıllardır pek çok ülkede doğal yağlar saçın bakımı için kullanılmaktadır. Yüzeyi yağlayarak kayganlığını, parlaklığını artırmak yanında, sürtünmeyi azaltarak günlük bakım işlemleri sırasında da daha az yıpranmasını sağladığı iddia edilmektedir.

Yağların korteks içine penetre ederek saçın mekanik özelliklerini artırabilmesi ise çok istenen yarar olarak söz edilmektedir [6-7].

AMAÇ

Bu çalışmada saç renginin açılmasının saçın bazı özelliklerini değiştirmesi ve kullanılan yağların saçın kaybedilen özelliklerini yeniden iyileştirme olasılığı araştırılmıştır. Bu amaçla Boabab yağı, keten tohumu ve badem yağları denenmiştirr.

MATERIALS & METHODS

Kullanılan saçlar, lokal kuaförlerden alınmış Türk kadın saçıdır
3 g ağırlığında , 20 cm uzunlukta ve 3,5 cm genişlikte tutamlar halide sıkıca dikilmiş olarak kullanılmıştır. Tek saç telleri olarak da kopmaya dayanıklılık ölçümleri için kullanılmıştır
Örnekler
1-Virgin (V) işlem görmemiş
2-B1 1 kez…… B7 7 kez renk açma işlemi yapılmış saç tutamı şeklinde hazırlanmıştır.
Saç acıcı ürün ve oksidan krem, ticari olarak satılan ürünlerdir ve işlemler kullanma talimatında verildiği şekilde uygulanmıştır.
Tutamlar Tablo 1'de formülü verilen şampuan ile yıkanmış ve bolca deiyonize su ile durulanmış, kilimalı odada tutulmuşlardır (25° C (±2)

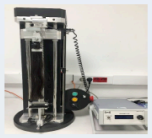
Material	Function	(%)
Texapon	Primary surfactant	12.00
Cocoamidopropyl Betaine Tegobetain	Co-surfactant	1.60
DMDM Hydantoin Glydant	Preservative	0.40
Sodium Chloride	Thickener	1.40
Distilled Water		to 100%

Table 1: Baz şampuan formülü

Coconut oil ve mineral oil pozitif ve negatif kontrol olarak kullanılmışlardır. Coconut oil is saç korteksine penetre edebilen, Mineral oil ise bu özelliği taşımayan yağlar olarak kullanılmaktadırlar [7]. Nile Red yağda çözülen bir boya olarak , ve floresan özelliğinden dolayı Şekil 3'te görülen saç enine kesit incelemesi için kullanılmıştır. Saç tutamlarından alınan 200-300 saç teli örnekleri (V ve B1….B7) , Nile Red içeren yağa konarak en az 10 dakika bekletilmiş, saçlar üzerindeki fazla yağ yumuşak kağıda emdirilerek alınmış tır. Parafine gömülen saç tellerinin dermatom ile enine kesitleri alınarak floresan mikroskop ile incelenmiş ve resimleri çekilmiştir.
Saç tutamlarının tarama testleri, gerilmeye dayanıklılık testi ve günlük bakım ve yaşlanmayı temsil eden GROOMING testleri yapılmıştır. Yeterli sayıda örnekle çalışılarak, gruplar arasındaki benzerlik ve farklılıklar istatistik olarak analizler edilmiştir.

Fiziksel özellikler 25°C (±2 °C) derece ve 50% (±5%) bağıl nem koşullarında bekletilen örneklerle , bu koşullarda yapılmıştır,
Testlerin yapıldığı ana cihazlar:
1- Hercules tarak (30 mm de 19 diş) takılmış saç tarama cihazı (Resim 4)
2- Kopmaya dayanıklılık testi (Resim 6) ve Grooming / Resim 5)
3- Floresan mikroskobu (Resim 3)

Şekil 3: Fluorescence Microscope (Zen blue 2012, Carl Zeis Microscopy)



Şekil 4: Tensile/Tarama kuvveti cihazı.

Tarama testi yapıldıktan sonra, tutamlar GROOMING cihazına takılarak dakikada 100 tarama yapacak şekilde ayarlanan cihazda 1000-5000 tarama yapacak şekilde test edilmiştir.
Bu test sonunda da
1-Kırılan saç telleri sayısı
2-uçları çatallanan saç telleri sayısı
tespit edilmiştir.
Mekanik özeliklerin incelendiği bu testlerin tümü
1- Virgin; işlem yapılmamış,
2- Rengi açılmış saçlar (Bleached B), işlem sayısı 1 ile 7 kez arasında değişmiştir.
3-Virgin saç ile ayrı ayrı 5 yağın etkisi için
4- Bleached saçlar için her biri grup için, ayrı ayrı her bir yağın etkisi için tekrarlanmıştır.
Tekrarlanan testler şunlardır:
-Tarama
-Kopmaya / gerilmeye dayanıklık(tensile strength)
-Grooming (Resim 5)
-Yağ penetrasyonu

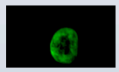
Şekil 5: Repeated hair grooming instrument.

Şekil 6: Tensile/Combing force cihazı ve çekmeyle kopma ataçmanları .

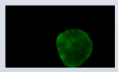
SONUÇLAR

Floresan Mikroskop İncelemeleri

Şekil 7: Virgin hair mineral oil

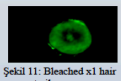


Şekil 8: Bleached x1 hair mineral oil

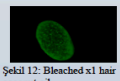


Şekil 9: Bleached x7 hair mineral oil

Şekil 10: Virgin hair coconut oil

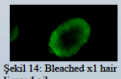


Şekil 11: Bleached x1 hair coconut oil

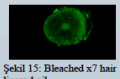


Şekil 12: Bleached x1 hair coconut oil

Şekil 13: Virgin hair linseed oil



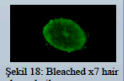
Şekil 14: Bleached x1 hair linseed oil



Şekil 15: Bleached x7 hair linseed oil

Şekil 16: Virgin hair almond oil

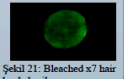
Şekil 17: Bleached x1 hair almond oil



Şekil 18: Bleached x7 hair almond oil

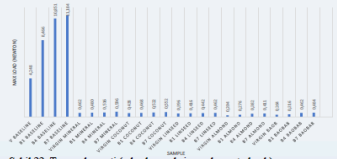
Şekil 19: Virgin hair baobab oil

Şekil 20: Bleached x1 hair baobab oil



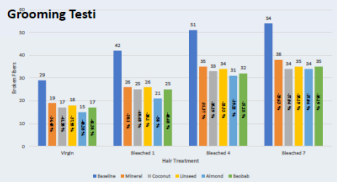
Şekil 21: Bleached x7 hair baobab oil

Tarama testleri



Şekil 22: Tarama kuvveti (ulaşılan maksimum kuvvet olarak)

Grooming Testi



Şekil 23: 5000 tarama sonra kırılan saç sayısı

Tensile Strength (Kopmaya/ gerilmeye dayanıklık)

	Virgin	Bleached x1	Bleached x3	Bleached x5	Bleached x7
Baseline	0,00	-5,09 %	-6,47 %	-14,99 %	-19,00 %
Mineral	-2,72 %	-3,74 %	-6,38 %	-15,56 %	-14,99 %
Coconut	4,65 %	-0,47 %	-1,01 %	-9,60 %	-11,67 %
Linseed	17,58 %	7,91 %	-3,02 %	-9,05 %	-10,43 %
Almond	3,37 %	1,19 %	0,25 %	-2,99 %	-9,80 %
Baobab	1,41 %	5,23 %	5,44 %	-4,72 %	-6,47 %

Tablo 2: Tensile strength ; Kopma anındaki kuvvetin % değişiklik cinsinden oranı. % değişiklik miktarı virgin saç ile hiçbir uygulama yapılmamışken alınan değerle karşılaştırılarak hesaplanmıştır.

TARTIŞMA

Şekil 8-9-11-12-14-15-17-18-20-21 çok açık bir şekilde saça renk açma işlemi uygulandığında yağın korteks içine penetre edebildiğini göstermektedir. Bu olgu kullandığımız tüm yağlar için geçerli olmuştur, negatif kontrol olan LP dahil olmak üzere. Çünkü kimyasal renk açma işlemi kütikula hücreleri arasındaki tiyoester bağlarını etkileyerek bozar. Ayrıca sistin açısından zengin bölgelerine, örneğin A-katmanı ile ekzo-kütikül arasındaki sistin amino asidini okside eder. Kütikül tabakası dökülme eğilimi gösterir. Derinin stratum korneum tabakası gibi, kütikül de saçın en dışını saran koruyucu duvarıdır. Soyulması halinde maddelerin korteks içine girmesi çok kolaylaşır. Çalışmamız sırasında negatif kontrol olan LP dahil tüm yağların korteks rengiaçılmış saç örneklerinin içine penetrasyonu bu yüzden mümkün olmuştur. Şekil 7'de görüldüğü gibi, kimyasal işleme tabi tutulmamış saçlarla ise (V), LP korteks içine penetre olmamış sadece yeşil bir halka halinde saç telinin etrafında görüntülenebilmiş, yani kütikülün üzerinde kalmıştır. Boabab yağı da penetre olamamış, ancak badem yağı ve keten tohumu yağları Coco yağı kadar olmasa da, korteks içine penetre olmuştur.

Tüm yağ uygulama işlemleri sonucunda, tutamlara uygulanan tarama kuvvetleri azalmıştır. Çünkü V veya B saç tutamlarında, kılların yüzeyi yağ ile kaplandığından, kayganlık artmış, saç telleri ve tarak dişleri arasındaki sürtünme kuvveti azalmıştır (lubrikasyon etkisi). Bu etki tüm yağlarla ve tüm saç tutamlarında gözlenmiştir, ancak badem yağı bu etkiyi en fazla gösteren yağ olmuştur. Bunun nedeninin, yağların film oluşturma özelliğine bağlı olabileceği düşünülmüştür.

Çekme ile kopma testlerinin sonuçları da Şekil 23'te özetlenmiştir. Saça uygulanan saç rengini açıcı işlem sayısı arttıkça kütikülün soyulma eğilimine paralel olarak saçın kırılganlığı da artmıştır. Tüm saç örneklerinde ve tüm yağ uygulamalarında, grooming testinde kırılan saç teli sayısı azalmıştır. Tablo 2'de özetlendiği gibi V saç ile keten tohumu yağı daha iyi ve Boabab yağı en az etkili olurken, B saç örneklerinde Boabab yağının etkisi olumlu olmuştur.

Bu çalışmanın sonucunda gözlenen saç tellerinin daha güçlü ve daha az kırılgan olmasının ne ölçüde penetre eden yağın kimyasal yapısına ve miktarına bağlı olduğunun araştırılması, bu tür test yöntemlerinin, saç bakımında kullanılan ürünlerle ilgili iddiaları destekleyen objektif test yöntemleri olarak geliştirilmesi sektöre önemli bir katkı olacaktır.

Kaynaklar

1. Velasco, M.V.R., et al., *Hair fiber characteristics and methods to evaluate hair physical and mechanical properties.* Brazilian Journal of Pharmaceutical Sciences, 2009. 45(1): p. 153-162.
2. Robbins, C.R., *Morphological, Macromolecular Structure and Hair Growth*, in *Chemical and Physical Behavior of Human Hair*, C.R. Robbins, Editor. 2012, Springer-Verlag Berlin Heidelberg. p. 1-104.
3. Fernandez, E., et al., *Photodamage determination of human hair.* J Photochem Photobiol B, 2012. 108: p. 101-106.
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5. Masukawa, Y., et al., *Damage to Human Hair Caused by Repeated Bleaching Combined with Daily Weathering during Daily Life Activities.* Exog Dermatol, 2004. 3: p. 279-281.
6. Gavazzoni Dias, M.F.R., *Hair Cosmetics: An Overview.* International Journal of Trichology, 2015. 7(1): p. 2-15.
7. Rele, A.S. and R.B. Mohile, *Effect of mineral oil, sunflower oil, and coconut oil on prevention of hair damage.* J Cosmet Sci, 2003. 54(2): p. 175-92.
8. Keis, K., et al., *Secondary ion mass spectrometric investigation of penetration of coconut and mineral oils into human hair fibers: Relevance to hair damage.* Journal of Cosmetic Science, 2005. 52(3): p. 169-184.

Appendix C3.1

KISA SÖZEL SUNUM PROGRAMI

SUNUM SALONU: KEKOVA - 23 ŞUBAT 2019 CUMARTESİ / 16:00-18:00

POSTER NO	YAZAR	BAŞLIK
(KS-PS-1)	**Buse OGEL**, Elif Begüm YILDIRIM, İrem BAHÇIVAN, Feyza Şebnem GÖRÜR, Naz GÜRBÜZ, Pelin İYİKÖŞKER, Ozan SAVAŞAN, Yasemin Yağan UZUNER	Krem Bazı Formülasyonları ve Aktif Madde Salınımı Arasındaki İlişkinin İncelenmesi
(KS-PS-2)	**Caner ACAR**, Kadri Gökhan ÖZOKAN	Anason *(Pimpinella anisum L.)* Uçucu Yağının Nanoemülsiyon Formülasyonlarının Hazırlanması ve Karakterizasyonu
(KS-PS-3)	**Essam TURKMANİ**, Yasemin Yağan UZUNER	Uygulanan Kimyasal İşlemlerin ve Bakım Ürünlerinin Saç Üzerindeki Etkileri
(KS-PS-4)	**Fatih ARICAN**, Sadık GÖNEŞ	Kolajen Peptit Üretimi ve Kozmetik Sektöründe Uygulama Alanları
(KS-PS-5)	**Feyyaz KÜTMÜR**, Seçil ÇAM	TEQPON AAB- Şampuan & Kişisel Bakım İçin Sülfatsız Yüzey Aktif Karışımın Elde Edilmesi ve Uygulama Alanları
(KS-PS-6)	**Kadri Gökhan ÖZOKAN**, Caner ACAR	Anason *(Pimpinella anisum L.)* Bitkisinden Doğal Koruyucu Ekstraksiyonu
(KS-PS-7)	Osman KOLA, **Mehmet Onur TÜRKDOĞRU**, Gökhan YILDIZ, Ömer Faruk GECESEFA, Kenan ERCAN, Aysel ESKİCİ, Ayşegül PARİM, Göknil İNANLI	**Şampuan İçerisine Eklenen Bitkisel Ekstrakt** Karışımının Antimikrobiyal Koruyucu Olarak Etkinliğinin Araştırılması
(KS-PS-8)	**Nilgün Güler KUŞÇULU**	Çeşitli Bitkilerin Özütlerindeki Fenolik Bileşiklerin Beyaz Saç Boyası Olarak Kullanımının İn-Vitro ve İn-Vivo Olarak Değerlendirilmesi
(KS-PS-9)	**Rasime DEMİREL**, İzel BAHADIR, Zuhal SAPAN, Oktay UYSAL, ENDER SUVACI	Tasarlanmış MicNo-ZnO Partiküllerinin Güneş Kremi Formülasyonlarındaki Mikrobiyolojik Etkinliği
(KS-PS-10)	**Selma YAZAR**	Güneş Koruyucu Ürünlerin Güvenliliği Konusunda Serbest Eczacıların Bilgi, Tutum ve Davranışlarının Değerlendirilmesi
(KS-PS-11)	**M. Tümerkan Kesim**, Ender SUVACI, Zühal SAPAN, Gürol DEMİREL	MicNo® Tozlarının Güneş Koruyuculuk Özelliği Olan Kozmetik Ürünlerde Kullanımı ve Mevcut Sektörel Sorunlara Çözüm Önerisi
(KS-PS-12)	**Yasemin Yağan Uzuner**, Demet Sezgin MANSUROĞLU, Erdi BULUS, Yesim Muge SAHİN	Diferansiyel Taramalı Kalorimetre İle Saç Ürünlerinin Etkilerinin İncelenmesi
(KS-PS-13)	**Fatih UÇKAYA**, Meryem UÇKAYA, Hatice Eda AKELÇİ	Antalya'da Yetişen Arum dioscoridis Bitkisi ve Bitkiden Hazırlanan Jel Formülasyonunun Antioksidan ve Anti-aging Aktivitelerinin İncelenmesi

Appendix C3.2

Effect of Different Oil Treatments on Hair

Yasemin Yağan Uzuner

On behalf of Essam Turkmani

23.02.2019

Giriş

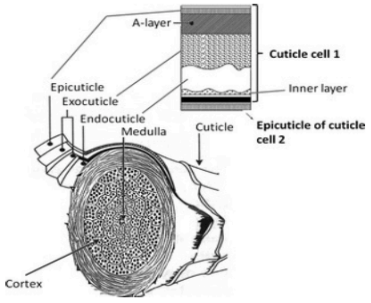

Figure 1: Schematic cross-section of a hair fibre showing medulla, cortex and cuticle cell layers

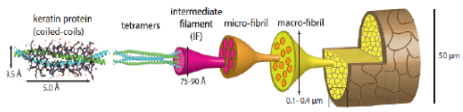

Figure 2: Schematic drawing of hair fiber showing the compononets of the cortex

Materials and Methods

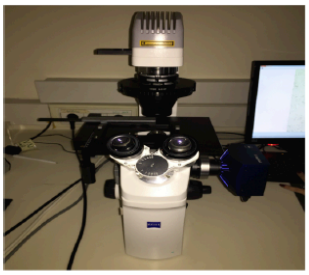

Figure 3: Flourescence Microscope

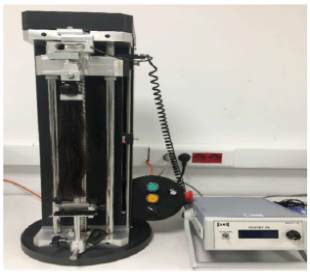

Figure 4: Tensile/Combing force device

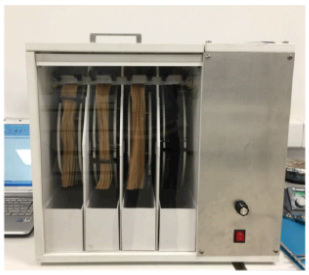

Figure 5: Repeated hair grooming instrument.

FluorescenFleurosance Micrøscopy

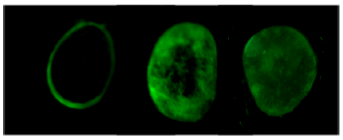

Figure 6: Mineral oil on V/B1/B7* hair

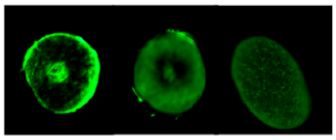

Figure 7: Coconut oil on V/B1/B7 hair

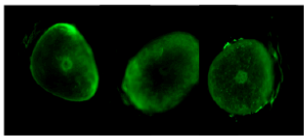

Figure 8: Linseed oil on V/B1/B7 hair

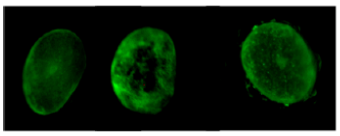

Figure 9: Baobab oil on V/B1/B7 hair

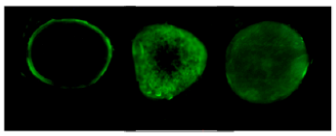

Figure 10: Almond oil on V/B1/B7 hair

* V: Virgin
B1: Bleached x1
B7: Bleached x7

Tarama kuvveti

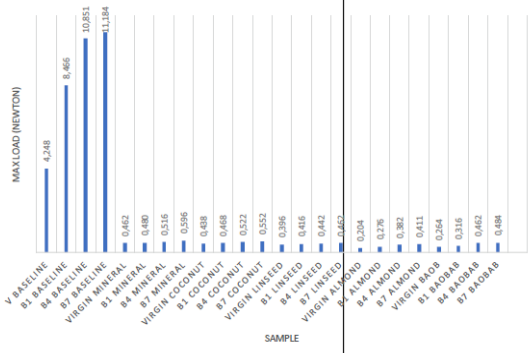

Figure 12: Combing forces max load of all studied samples (According to oil treatment)

Repeated Grooming

	Baseline				Mineral Oil				Coconut Oil				Linseed Oil				Almond Oil				Baobab Oil			
Cylces	V	B x1	B x4	B x7	V	B x1	B x4	B x7	V	B x1	B x4	B x7	V	B x1	B x4	B x7	V	B x1	B x4	B x7	V	B x1	B x4	B x7
1000	14	16	20	23	9	12	14	15	8	11	13	13	8	12	13	14	7	10	11	13	7	11	12	13
2000	5	8	13	14	5	6	8	11	3	4	8	10	3	5	9	9	3	6	8	8	5	5	8	9
3000	4	7	9	8	3	3	7	5	3	5	5	5	3	4	5	6	2	3	5	7	2	5	5	6
4000	3	7	5	6	1	3	4	4	1	4	4	3	2	4	5	4	2	1	5	4	2	3	5	4
5000	3	4	4	3	1	2	2	3	2	1	3	3	2	1	2	3	1	1	2	2	1	1	2	3
Total	29	42	51	54	19	26	35	38	17	25	33	34	18	26	34	36	15	21	31	34	17	25	32	35

Table 1: Typical repeated grooming data for all samples after 5000 brushing strokes

Repeated Grooming

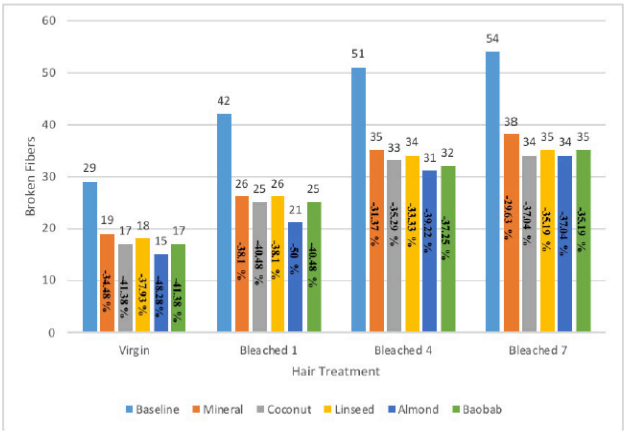

Figure 13: Total broken fibers after 5000 brushing strokes according to type of hair

Results

	Virgin	Bleached x1	Bleached x3	Bleached x5	Bleached x7
Baseline	0	-5,09 %	-6,47 %	-14,99 %	-19,00 %
Mineral	0	-0,03 %	-2,97 %	-12,30 %	-11,79 %
Coconut	0	-4,89 %	-5,41 %	-13,61 %	-15,59 %
Linseed	0	-8,23 %	-17,52 %	-22,65 %	-23,83 %
Almond	0	-2,11 %	-3,01 %	-6,15 %	-12,74 %
Baobab	0	3,79 %	3,98 %	-6,04 %	-7,77 %

Figure 14: Stress at break percentage changes for each oil treatment after bleaching

Results

.

	Virgin	Bleached x1	Bleached x3	Bleached x5	Bleached x7
Baseline	0,00	-5,09 %	-6,47 %	-14,99 %	-19,00 %
Mineral	-2,72 %	-3,74 %	-6,58 %	-15,56 %	-14,99 %
Coconut	4,65 %	-0,47 %	-1,01 %	-9,60 %	-11,67 %
Linseed	17,58 %	7,91 %	-3,02 %	-9,05 %	-10,43 %
Almond	3,37 %	1,19 %	0,25 %	-2,99 %	-9,80 %
Baobab	1,41 %	5,25 %	5,44 %	-4,72 %	-6,47 %

Figure 15: Stress at break percentage changes for each oil treatment compared to virgin baseline

8 CURRICULUM VITAE

Personal Information

Name	Essam	**Surname**	Turkmani
Birth place	Homs – Syria	**Date of Birth**	25.08.1990
E-mail	essam.turkmani@gmail.com	**Tel.**	00905398387288

Education

Degree	**Field**	**Name of Institute**	**Graduation Year**
B.Sc	Pharmacy	Al-Kalamoon University	2014
High School	School of science	Albasel Gifted Students School	2009

Languages

Arabic	Mother tounge
English	Fluent
Turkish	Basic

International Tests Scores

TOEFL PBT	603	2015
GRE Quantitative Reasoning	157	2016

Computer Skills

Microsoft Office (Excel – Word – PowerPoint)	Intermediate
SPSS	Intermediate