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abstract

Do you know your hair type and its unique needs?

Let us explore the science behind various hair types and examine consumer challenges, goals, aspirations, and routines. By understanding the differences and similarities among different hair textures, we aim to address existing gaps in hair care. This knowledge empowered us to tailor an innovative hair care ingredient, derived from *Ilex paraguariensis*, designed to effectively manage and redefine the hair vibe with biohacking expertise. With YERBALUXE®-CROWN (hereafter *Ilex paraguariensis* leaf extract; INCI: Water, Pentylene Glycol, Ilex Paraguariensis Leaf Extract, Citric Acid) we can effectively meet the unique needs of consumers with different hair types. Inclusion is essential also in hair care, but having the right knowledge is the way to set the base for consumer tailored solutions.

Introduction

Let us start by clearing up the common “ethnic terms such as Asian, Caucasian, and African hair”. This classification excludes many unique hair-type groups and does not reflect real state of hair diversity. Genotyping studies have shown that the African population predominantly has curly hair (94.9%), with a small percentage having wavy hair (5.1%). In contrast, the Asian population exhibits a more diverse range of hair types: 46.7% have straight hair, 41.3% have wavy hair, and 12% have even curly hair. Among people of European ancestry, 46.6% have wavy hair, 40.7% have straight hair, and 12.7% have curly hair. Notably, curly hair is prevalent worldwide, with an incidence rate exceeding 50% [1]. Hair curliness is a distinct human characteristic, and straight hair seems to be new on the hairy timeline of human evolution [2]. Therefore, instead of relying on ethnic ancestry, it is more accurate to consider specific characteristics such as curl pattern, hair shaft diameter, or lipid content. These factors can vary widely even within the same ethnic group, making

it important to assess hair on an individual basis. By focusing on these attributes, we can better understand how to care for and celebrate the unique beauty of every person’s hair.

| | Coily (V) | Curly (III) | Straight (I) |
|--|---|---|--|
| Hair follicle growth relative to scalp surface | Parallel | Diagonally | Perpendicular |
| Shape of the hair shaft | Flattened Asymmetric in shape and cellular/keratin distribution | Oval Asymmetric in shape and cellular/keratin distribution | Round Symmetric in shape and cellular/keratin distribution |
| Hair lipids quality and amount (a.u.) | Apolar and unsaturated lipids (sterol esters and squalene) | Higher amount of free fatty acids | More polar lipids |
| (cuticle, cortex, medulla) | 0.946, 0.9, 2.894 | 0.426, 0.580, 1.183 | 0.662, 0.504, 2.367 |
| Hair diameter (µm) | 55 | 65 | 80-120 |
| Hair density (hairs/cm²) | 161± 50 | 226 ± 73 | 175 ± 54 |
| Number of hairs on scalp | 50'000-100'000 | 86'000 - 146'000 | 80'000-140'000 |
| Growth rate (µm/day) (Mean ± SD) | 280 ± 50 | 367± 56 | 411 ± 53 |
| Sebum production rate | High | Middle | Low |
| Hair shaft hydration | Low | High | Low |
| Cuticle quality | High incidence of damage, higher friction coefficient, higher torsional rigidity, less lustre | More fragile and collapse into small pieces upon extension | More layers and thicker, peels off as large fragments upon extension |
| Tensile strength | Inverse correlation between curliness and strength, and curliness and diameter | | Stronger than other types |

Table 1: Common grounds and differences between hair type V, III and I.

The most widely recognized hair classification systems are Andre Walker's and L'Oréal's Hair Typing Systems. The first categorizes hair into four main types – straight, wavy, curly, and kinky – and further refines these categories using a letter system. However, this system relies on qualitative measures, which can be vague and may not fully capture the diversity of hair phenotypes. L'Oréal's system, on the other hand, is based on quantitative geometric parameters and identifies eight categories (I – VIII). This system is recognized as the official standard for hair typing in both the personal care industry and academia [3]. In order to accurately represent hair characteristics, we have selected three specific hair types for more in detailed analysis, namely type V, III and I. Some of the parameters showing similarities and differences between those hair types are depicted in the **Table 1**. Those characteristics are defining physical behaviour of the fibres and are essential in creating specific hair care for different hair types (**Table 1**) [4-6].

Each hair type has unique properties and therefore requires a special care. Nevertheless, textured hair requires the most demanding daily routine. And unfortunately, especially the consumer with hair types V-VIII experience a big gap regarding the products and routines satisfying their needs [7]. There is a huge lack of trust and skilled experts for this type of hair. Those consumers have a strong self-awareness due to the bad experience and they are most likely to create DIY products or modify existing ones. The "Textured Gap Report" says the tighter the hair texture the higher the likelihood of multiple concerns, such as dryness (70%), slow growth (66%) and breakage (59%). In addition, scalp dryness, itchiness, flakiness, and product build up are top scalp concerns for consumers with textured hair – almost the double if compared to hair type II cohort.

In general, our hair – no matter the hair type – experiences stress daily, even in the tranquillity of sleep. Since damaged hair cannot be repaired, it needs a supportive daily hair care routine to keep the locks healthy, vibrant and full of life.

Ilex paraguariensis leaf extract captures the magic of mate tea and tackles the problems of daily and nightly hair care routines for all kinds of hair types, which was substantiated with hair types V, III and I. *In-vivo* study showed improvement in different hair sensory parameters for consumers with type V hair. *Ex-vivo* studies have shown that *Ilex paraguariensis* leaf extract protects hair ceramides, locks-in hydration and restructures damage. Furthermore, it reduces frizz, hair tangling, maintains curls naturally and increases hair softness after just one shampooing. This RAHN-Cosmetic Actives signature plant, *Ilex paraguariensis*, contains approximately 13 times the amount of polyphenols, twice the amount of caffeine and about 8 times the amount of rutin compared to freshly brewed yerba mate tea. It is a powerful, and traditional energising drink to the hair, offering extraordinary benefits after one single application.

Materials and methods

Subjective perception: 60 volunteers with hair type V (virgin and coloured hair, different damage degree) have been included and divided in placebo and verum group. A treatment with a shampoo (placebo or 0.5% verum) along with a light leave-on conditioner (placebo or 0.2% verum) have been used daily at home during a period of 14 days. Different hair sensory parameters have been evaluated by study participants on a scale ranging from 1 (poor) – 7 (excellent) at D14. Scores 5 to 7 (good, very good and excellent) are considered positive for the evaluation.)

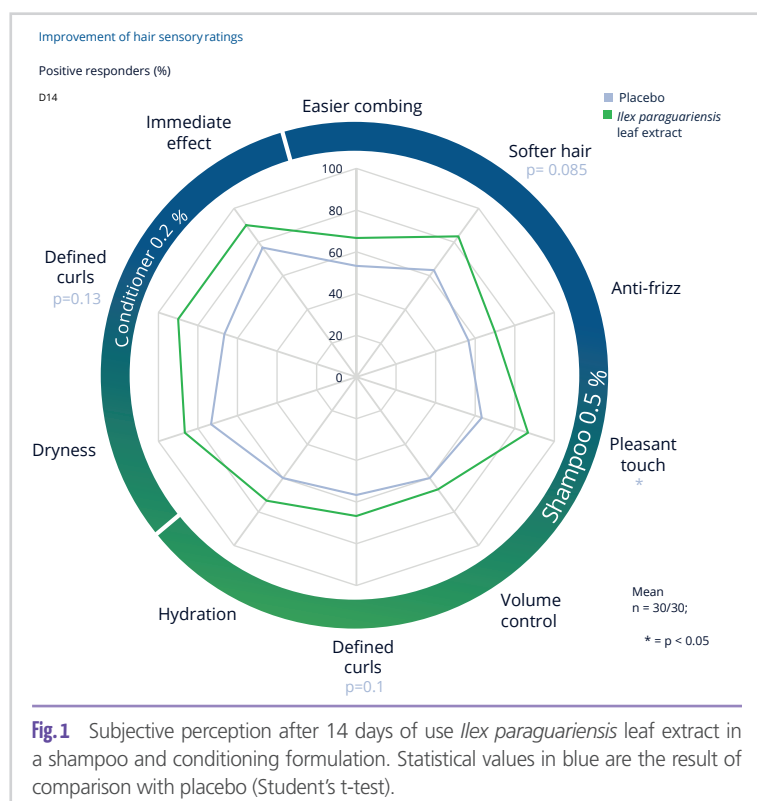
Ceramides protection: Four different treatment groups (virgin hair, type I) have been prepared, namely untreated control, stress control, shampoo treatment with either placebo or verum (0.5%). All samples, except untreated control, have been subjected to heat stress (95°C) for one hour. After cryo-section (5 µm), samples have been labelled with a monoclonal anti-ceramide antibody, followed by fluorophore coupling. Fluorescent images were collected and analysed.

Hydration lock-in: Bleached hair tresses (hair type V, III and I) were cut into 5 cm sections after a single rinse-off treatment (0% or 0.5%) and Differential Scanning Calorimetry (DSC) analysis was performed (in duplicates) totalling 10 data sets on hydration per treatment (Hitachi High-Tech Sciences TA7000 Series Simultaneous Thermogravimetric Analyzer, STA7200). Hydration was mapped by a software correlating numeric value of enthalpy of water vaporisation ($100 - 300 \text{ J / g}$, ΔH_{vap} , 25°C – 180°C).

Damage restoring: To evaluate the damage caused by bleaching, the hair tresses (hair type V, III and I) were immersed in a Rhodamine B solution for 2 minutes to mark the damaged areas after a single rinse-off treatment (0% or 0.5 %). Fluorescence spectroscopy analysis (FluoroMax 4® – Horiba, Model TCSPC; Ex. 554 nm, Em. 580 nm) was performed before and after exposure to Rhodamine B. Damage was mapped and represented by a software correlating numeric value of fluorescence intensity (scale 0 – 1 000 000 a.u.) to a colour (blue-red).

Anti-frizz efficacy: To induce static charge and frizz, the bleached hair tresses underwent a standardized manual brushing procedure (hair type V, III) or exposure to the Van der Graaff generator for 1 minute (hair type I) after a single rinse-off treatment (0% or 0.5%). Photographs were taken.

Hair untangling: To simulate the movement during sleep, virgin hair tresses (hair type V, III and I) were submitted to the night routine in a standardized device – exposition to mechanical stress between a static foam and a rotating foam (equivalent to movements during 8 h of sleep; cycle duration 1 minute). The assessment of the hair fibres organisation was



performed by analysing Fast Fourier Transform (FFT) spectra, followed by the Radial Plot Profile from the centre of the spectrum. The increase of the full width at half maximum (FWHM) of the curve indicates the loss of the image pattern, that is the appearance of disorder in the system. The FFT spectra of untreated tresses, tresses after the washing step (shampoo with 0% and 0.5% *Ilex paraguariensis* leaf extract) and treated tresses after the night routine were recorded and evaluated.

Curls maintenance: Virgin curly hair tresses (type III) were rolled on Teflon cylinders after the single rinse-off treatments (0% or 0.5%) and dried for 24 h. After drying, the tresses were unwound, and initial images were taken. Subsequently they were left to rest for additional 24h in a controlled environment (55% ± 5% relative humidity and 22 ± 2°C). Pho-

tographs were taken and variations in length compared to initial condition were calculated.

Hair softness: The Ring Method (Instron 23-2S, software Bluehill, 30 mm and 23 mm diameter rings) was used to assess the force required to pull a double-bleached hair tress (hair type III, single rinse off treatment with 0% and 0.5% verum) through rings of varying diameters. By analysing the force required, we can deduce the hair's elasticity, roughness, and compressibility, which collectively describes the softness of the hair.

Results

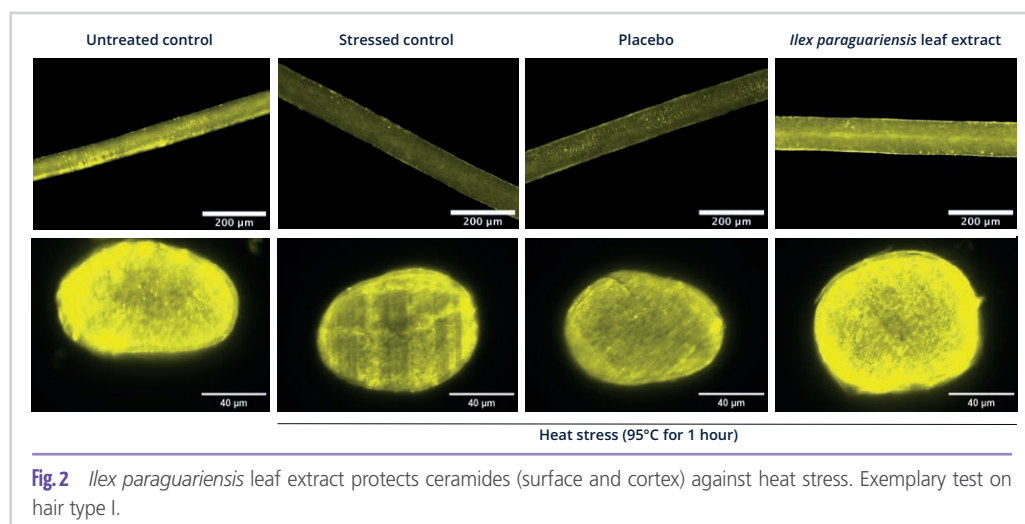
Subjective perception: After 14 days of treatment, which included daily use of shampoo and conditioner, self-assessed parameters showed partly improvement. The use of shampoo and conditioner improved clearly outperformed placebo treatment up to 23% (Figure 1).

Ex-vivo studies: The ex-vivo experiments conducted on hair tresses have demonstrated that *Ilex paraguariensis* leaf extract can enhance various parameters after a single shampoo application. The following tests provide scientific support for the in-vivo efficacy of the extract.

Ceramides protection:

A visual decrease in ceramide levels on hair fibre-surface (cuticle) and within the hair shaft (cortex, medulla) is observed upon deleterious heat-stress (stressed control, Figure 2), when compared to untreated control group. Placebo samples displayed similar stress-induced ceramide depletion/degradation. Treatment with 0.5% *Ilex paraguariensis* leaf extract resulted in highly protected ceramide. Quantification of the ceramides on hair fibre surface (top panels) revealed significant protective efficacy up to 32%, while protection efficacy in the cortex (lower panels) was 49% when compared to placebo treatment.

Hydration lock-in: Increased hydration or hydration variation within the hair shaft breaks hydrogen bonds and may lead to hair swelling and damage [8]. Well-sealed cuticula prevents the water exchange and maintains water within hair shaft. According to the results, tresses submitted only once to 0.5% *Ilex*



paraguariensis leaf extract showed significantly higher mean values of enthalpy of water vaporization ΔH_{vap} when compared to placebo (Figure 3). This means that the energy to evaporate the water out of the hair was significantly higher than in placebo samples. This indicates better sealing of the hair and better maintenance of the hair structure, which can be attributed to hydration retention. *Ilex paraguariensis* leaf extract increased ΔH_{vap} by 16% for hair type V and II and by 17% for type I if compared by placebo.

Damage restoring: Chemical treatments typically cause significant damage to all parts of the hair, with the tips – the oldest section – being particularly affected. However, applying a 0.5% concentration of *Ilex paraguariensis* leaf extract resulted in a significant reduction in hair damage to all parts of the hair. Remarkably, after just one wash, all sections of the hair exhibited less Rhodamine B penetration leading to the decreased fluorescence, highlighting the damage-restructuring effectiveness of the extract. Overall, the treatment reduced hair damage significantly by 38% in type V, 28% in type III and 18% in type I hair. Visualisation of the damage is shown in the Figure 4 for hair type V.

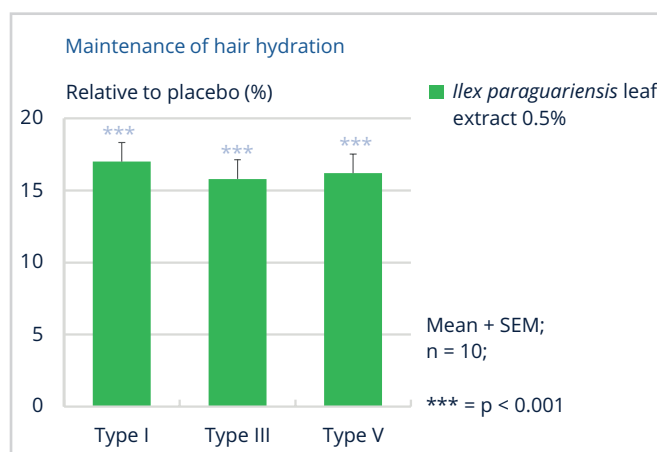


Fig. 3 *Ilex paraguariensis* leaf extract improves maintenance of moisture in hair. Statistical values in blue are the result of comparison with placebo (Student's t-test).

Anti-frizz efficacy: The treatment with 0.5% *Ilex paraguariensis* leaf extract showed significantly lower frizz compared to placebo treatment. Static charge of hair has been reduced up to 4.3% for hair type I, 2.8% for hair type III, and 1.6% hair type V (Figure 5).

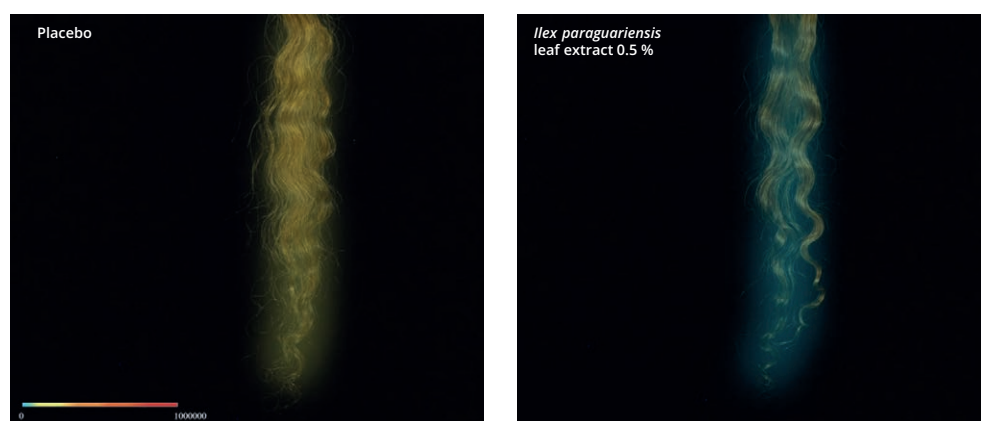


Fig. 4 *Ilex paraguariensis* leaf extract reduces damage after chemical treatment. Exemplary picture of hair type V.

Hair untangling: The natural curl pattern and dryness of textured hair tends to cause interlocking and tangling during sleep routine. So, caring for textured hair needs much more attention and it needs to be extended even over the night. The analysis demonstrated that following the washing step, samples treated with 0.5% *Ilex paraguariensis* leaf extract exhibited already

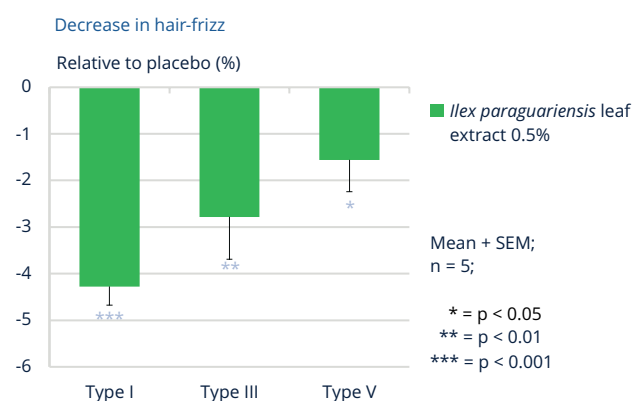


Fig. 5 Anti frizz efficacy of *Ilex paraguariensis* leaf extract on three different hair types after one single washing. Exemplary picture of hair type I is shown on the right. Statistical values in blue are the result of comparison with placebo (Student's t-test).

a significant reduction in disorganization compared to the untreated samples. In contrast, no difference was observed in the placebo group. After the night routine (corresponding to the regular sleep movement), the placebo samples experienced increased interlocking and tangling due to the sleep routine (Figure 6). The result for the extract was similar to the initial condition. The reduction in disorganization between the placebo and the *Ilex paraguariensis* leaf extract treatment was 84% for type V hair type (43% for type III and 61% for type I, data not shown). *Ilex paraguariensis* leaf extract effectively maintained the organization of hair and minimized interlocking and tangling after the night routine.

Curls maintenance: The treatment with different concentrations of *Ilex paraguariensis* leaf extract demonstrated a dose-dependent effectiveness in curl retention. Curls were notably more defined and sustained with a single shampoo treatment containing 1% of extract, showing a 12% improvement over the placebo treatment (Figure 7). While the treatment with 0.5% extract indicated a trend towards improvement, it was not statistically significant.

Hair softness: A single treatment with 0.5% *Ilex paraguariensis* leaf extract significantly reduced the power required to pull hair tresses through rings. This treatment demonstrated superior softness enhancement, improving it by 110% compared to the placebo treatment.



Fig. 6 The natural curl pattern and dryness of textured hair tends to cause interlocking and tangling during sleep. *Ilex paraguariensis* leaf extract keeps curls organised and reduces the interlocking and tangling. Exemplary picture for hair type V.

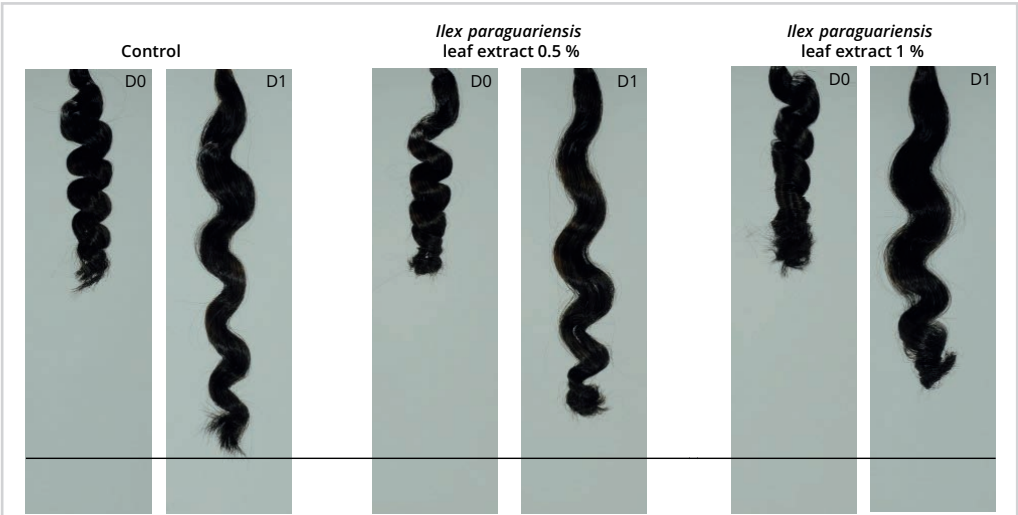


Fig. 7 *Ilex paraguariensis* leaf extract maintains curls (hair type III) naturally.

Discussion

We have explored the diverse characteristics of different hair types and the challenges faced by consumers in managing them. This study emphasizes the importance of understanding hair diversity beyond traditional ethnic classifications, focusing instead on specific attributes such as curl pattern, hair shaft diameter, and lipid content. This approach allows for a more individualized assessment of hair care needs.

We highlight the *Ilex paraguariensis* leaf extract's ability to cater to the unique needs of different hair types, particularly those with higher curl patterns, which often require more demanding care routines. Through both *in-vivo* and *ex-vivo* studies we demonstrated significant improvements in hair health, appearance and manageability. By leveraging the bioactive properties of *Ilex paraguariensis*, the study offers a tailored approach to hair care that aligns with the growing demand for inclusive and effective solutions. The findings underscore the importance of scientific research in developing innovative cosmetic products that address specific consumer needs, ultimately contributing to the advancement of personalized hair care.

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