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Innovative Methods for Selecting Personal Care Products, based on the Application of Knowledge of the Chemical Composition and Properties of Hair

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Abstract

The article analyzes a fundamental challenge of contemporary cosmetology: the mismatch between high consumer demand for lightened hair and the inevitable chemical destruction of its keratin matrix. The aim of the study is to scientifically substantiate and analytically verify the Zelenska Beauty Blonde System methodology as an integrated model that minimizes cumulative damage to the hair shaft. The methodological strategy is interdisciplinary and combines a systematic review of the literature on the biochemistry and proteomics of hair. The data obtained demonstrate that lightening initiates irreversible oxidation of keratin disulfide bridges with the formation of cysteic acid, which is accompanied by a progressive decrease in tensile strength (up to 50% after three procedures) and leaching of protein components. The proposed system, based on strategic planning of coloring sessions, personalized care, and client education, makes it possible to increase the intervals between aggressive exposures (from 1,5–2 to 5–6 months), thereby reducing the chemical load and maintaining the structural integrity of the hair. It is concluded that a systemic, evidence-oriented approach ensures long-term high hair quality while simultaneously meeting the current consumer demand for expertise and personalization, strengthening sustainable client loyalty. The results presented are relevant for cosmetic chemists, trichologists, and practicing hairdressing professionals.

Keywords: *Hair Lightening, Keratin Damage, Disulfide Bonds, Cysteic Acid, Systems Approach, Personalized Care, Trichology, Consumer Loyalty, Cosmetology, Zelenska Beauty Blonde System.*

INTRODUCTION

Hair coloring, especially lightening, remains one of the key and most economically significant services of the beauty industry. Against sustained demand, consumer expectations are being reoriented. Analytical reviews indicate a projected average annual growth of the global cosmetics market of 5% to 2030, accompanied by intensified critical attitudes toward marketing claims and a shift of attention to proven efficacy and real product value [1]. Under these conditions, priority is given to methodologies that provide not a short-term visual effect, but a long-term, scientifically verifiable solution to the client's objectives [2].

The scientific problem of this work arises from a fundamental contradiction between the chemical nature of lightening and the biological architecture of the hair. Lightening is based on intensive oxidation, in which the destruction of the natural pigment melanin is coupled with irreversible degradation of keratin, the main structural protein of the hair shaft. This determines a decrease in mechanical strength, an increase in porosity, pronounced dryness, and brittleness — precisely the manifestations most often reported by clients and encountered by professionals.

An analysis of the scientific literature and market practices reveals a significant gap between the depth of biochemical knowledge about damage mechanisms and the industry's dominant fragmented, predominantly transactional service approaches. Strategies that mask consequences prevail instead of their systematic prevention. There is a lack of formalized integrated solutions that translate fundamental principles into a long-term client strategy focused on preserving the structural integrity of the hair shaft.

The author's hypothesis is that a systemic integrated protocol combining strategic planning and minimization of chemical interventions, personalized selection of home care based on scientific data, and targeted client education can reduce the damaging effects of lightening. The expected

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outcome is a sustained improvement in the qualitative characteristics of the hair and the formation of high client loyalty based on trust and measurable results.

The aim of the study is to analyze and substantiate the Zelenska Beauty Blonde System methodology as an interdisciplinary model that effectively addresses chemically induced damage to lightened hair and meets current consumer demands.

The scientific novelty lies in the systematization and verification of a comprehensive approach to the care of lightened hair that unites biochemical foundations, practical cosmetology tools, and consumer behavior analysis.

MATERIALS AND METHODS

The corpus of sources on the topic is reasonably considered in four blocks — strategic market orientations, fundamental biophysics of damage, diagnostic/methodological approaches, and interventional solutions with commercial personalization.

In the strategic block, the authors note the complication of demand and the need for evidence-based personalization as a source of differentiation under margin pressure and channel fragmentation.

In the biophysics and damage block, the structure of the cuticle/cortex and the functions of the lipid-protein matrix are systematized as a basis for understanding fiber vulnerabilities; the influence of scalp condition via oxidative stress on hair growth and retention is analyzed, elevating personalization to the unit level: scalp + shaft.

In the diagnostic-methodological block, the authors compare extension in wet and dry states and demonstrate differences in the sensitivity and interpretability of metrics, which limits the transferability of laboratory wet indicators to dry consumer perception.

In the interventional block, the researchers demonstrate the photoprotective action of hydrolyzed keratin as a reduction of protein photodegradation and preservation of mechanical/optical properties (a basis for preventive recommendations along solar and oxidative trajectories).

However, contradictions exist across studies, and methodologically a gap persists between laboratory metrics and consumer outcome: results of wet tests are not equivalent to the dry experience, whereas market metrics often conflate them. Commercial personalization systems are predominantly visual-questionnaire based and weakly integrate omics data on the shaft and redox markers of the scalp, leaving recommendations chemically mute to the actual damage type. Interventional results are promising, but long clinical studies with consumer-relevant endpoints are rare (shine/friction on a dry tress, color retention after N cycles). The damage passport that couples TEM/proteomics/mechanics with user sensations remains insufficiently standardized.

RESULTS AND DISCUSSION

Hair lightening is a sequential, chemically aggressive procedure aimed at the destruction of melanin pigments concentrated predominantly in the cortical layer. The process is initiated by exposure to an alkaline component — most often ammonia or its derivatives — which induces swelling of the hair shaft and lifts the cuticle scales, that is, the outer protective barrier [3]. Such weakening of the barrier function is necessary for diffusion of the main oxidant, hydrogen peroxide (H_2O_2), deeper toward the cortex. It has been shown that the primary structural damage to the cuticle facilitates subsequent penetration of the oxidant, forming a positive feedback loop in which each repeated procedure amplifies the total structural degradation [4].

The key molecular event is the irreversible oxidative cleavage of disulfide bonds (–S–S–) in cystine residues that crosslink keratin polypeptide chains and provide the strength and elasticity of the hair's three-dimensional framework. In the presence of hydrogen peroxide in an alkaline medium, each such bond is converted into two cysteic acid residues (–SO_3–) [4]. Schematically, this step is shown in Fig. 1.

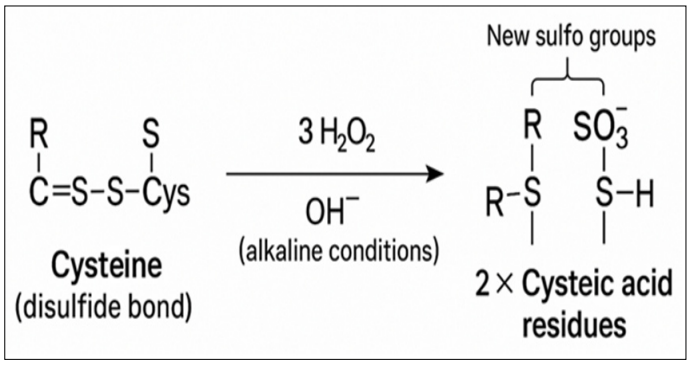


Fig. 1. Scheme of the mechanism of oxidation of the disulfide bond (compiled by the author based on [3, 4]).

This chemical modification triggers a cascade of physical consequences. The replacement of strong, covalent, hydrophobic disulfide bridges with highly polar, negatively charged cysteic acid groups gives rise to two principal effects. First, the mechanical load-bearing capacity decreases sharply, because the primary force-bearing framework of the protein architecture is destroyed. Second, the surface properties of the hair shift from hydrophobic to markedly hydrophilic [6]. This explains the clinical appearance of lightened damaged hair: the fibers intensively sorb moisture (including from the air) and swell, but do not retain it, establishing a persistent cycle of desiccation, frizz, and increased porosity [11].

The consequences of oxidative stress are not limited to disulfide bond scission. Proteomic data indicate that the chemical attack initiates leaching of protein components from the hair shaft, affecting not only the cuticle but also deeper layers—the cortical intermediate filaments and

keratin-associated proteins (KAPs) [5]. Contemporary proteomic studies confirm that lightening substantially reduces sequence coverage of keratins and KAPs, indicating the loss of structural protein fragments [12].

This degradation of structural integrity is captured directly as a decrease in tensile strength. Quantitative tests demonstrate progressive weakening of hair with each subsequent lightening procedure, as reflected in Table 1.

Table 1. Progressive decrease in tensile strength of bleached hair (compiled by the author based on [5, 9, 12]).

Treatment stage	Tensile strength (MPa)	Reduction from initial (%)	Key structural changes
Natural hair (virgin)	120.24	0%	Intact cuticle, preserved disulfide bonds.
1st bleaching	100.32	16.6%	Partial lifting and erosion of the cuticle, onset of oxidation of S-S bonds.
2nd bleaching	80.45	33.1%	Marked cuticle damage, extensive conversion of cystine to cysteic acid.
3rd bleaching	60.12	50.0%	Critical loss of the cuticular layer, deep cortex damage, loss of protein mass.

The data in Table 1 convincingly demonstrate the effect of damage accumulation: each new aggressive exposure occurs on an already weakened substrate and, consequently, amplifies structural degradation. Hence the practical conclusion follows: the strategic reduction in the frequency of such procedures is an important condition for preserving hair health.

In parallel with the deepening of scientific understanding of hair morphology and biology, the consumer landscape is also transforming. Contemporary trends are generating demand for more evidence-based, science-intensive, and individualized care. A key direction is skinification, that is, the transfer of the principles and active components of dermatologic cosmetology into trichological practice [14]. The basic premise is clear: the condition of the hair is inseparable from the condition of the scalp. Experimental and clinical data demonstrate that the scalp functions as an incubation medium for the developing hair shaft, and oxidative stress on its surface (including that driven by microbial activity or inflammation) worsens shaft properties even before its emergence [15]. This provides a logical rationale for the need for a holistic approach that includes assessment of skin status and consideration of general somatic determinants—above all, nutrition and stress level [16].

Another strong vector is hyperpersonalization, grounded in technological solutions. The consumer is increasingly rejecting generic products in favor of individually designed regimens. At the forefront are integrated systems that leverage digital (including AI) diagnostics to analyze hair type and current state, porosity, and lifestyle features, followed by the construction of customized formulas and care programs [14].

Against this background, the paradox of choice becomes especially pronounced: an oversaturated market with thousands of weakly differentiated offerings and aggressive marketing provokes anxiety, decision fatigue, and, as a result, dissatisfaction with the final choice [19]. Under such conditions, increasing value accrues not to assortment expansion but to qualified expertise that filters informational noise and offers a clear, well-substantiated plan of action. The consumer seeks not only a product but also a mentor-navigator within the complex system of self-care. The focus shifts from the recognizability of the brand founder to the proven efficacy of the product and trust in the recommending expert (Fig. 2).

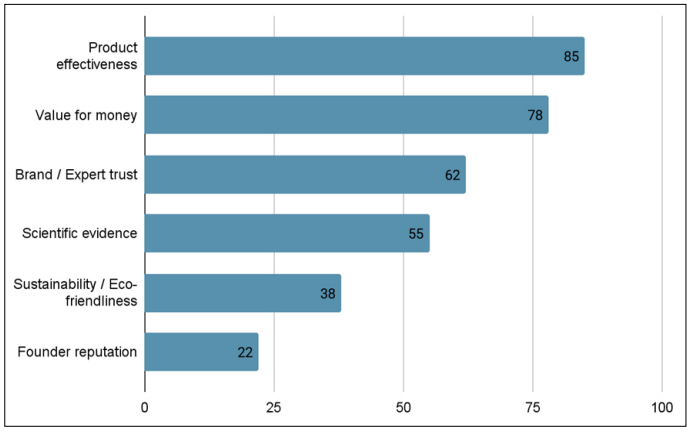


Fig. 2. Key factors of consumer value in the cosmetics market in 2024-2025 (compiled by the author based on [1, 2, 19]).

Thus, the most successful solutions are those that simultaneously address the technological task (e.g., lightening/coloring) and relieve the client of the cognitive-emotional burden of choice, replacing it with justified confidence grounded in expertise and personalization.

The Zelenska Beauty Blonde System methodology constitutes a practical manifestation of a systemic, scientifically verified approach capable of responding both to the biochemical challenges of lightening and to current consumer expectations. Decomposition of the methodology into functional blocks reveals a strict correspondence between each of them and the previously described scientific principles.

The initial stage sets the foundation of the entire construct. A thorough assessment of hair condition, everyday care habits, and the history of prior coloring aligns with the trend of hyperpersonalization [18]. In scientific terms, this enables determination of the baseline level of damage (a cumulative

effect reflected in Table 1) and the formation of a strategy that will not exacerbate existing degradation but will be directed toward its correction.

Next follows the stage at which an individualized plan and coloring strategy are prepared. This is the central mechanism for damage limitation. The proposed smooth color stretch, which increases the interval between aggressive root lightening from 6–8 weeks to 5–6 months, constitutes a direct, instrumentally implementable response to the problem of cumulative chemical injury. Replacing frequent total lightening with intermediate procedures of gentle toning and intensive care makes it possible to maintain the required aesthetic result while sharply reducing the chemical load on the keratin matrix.

The next step is accompaniment and education. The integration of elements such as the Hair Care Guide and workshops translates the service into a mentorship format. This component specifically neutralizes the paradox of choice: rather than leaving the client alone with the retail assortment, it offers a curated set of products and, crucially, an understanding of the logic of their use. As a result, a sense of control and predictability is formed, stress is reduced, and trust in the specialist is strengthened [13, 17].

The analysis of the presented case serves as a longitudinal demonstration of the effectiveness of the described approach. The baseline condition of the client with frequent lightening (every 6–8 weeks) and a sharp contrast of regrown roots is characterized by dryness and brittleness. This is a typical vicious-circle configuration in which each subsequent intervention exacerbates the damage accumulated by prior procedures. Transition to increasing the interval between lightening sessions to 5–6 months allows the restoration of hair fiber quality (softness, shine, density) and creates the possibility of growing length. The system effectively interrupted the cycle of damage accumulation.

In Table 2, a more extensive comparative analysis of the two approaches will be presented, which systematizes their key differences.

Table 2. Comparative analysis of approaches to the care of lightened hair (compiled by the author based on [7, 8, 10]).

Parameter	Traditional approach	Zelenska Beauty Blonde System
Frequency of root lightening	High (every 1.5–2 months)	Low (every 5–6 months)
Chemical load	Maximal, cumulative	Minimized, strategic
Focus of care	Masking of damage	Prevention of damage, restoration of structure
Role of the client	Passive recipient of the service	Active, trained partner in the process
Long-term outcome	Progressive degradation of hair quality	Maintenance and improvement of hair quality, possibility of growing length
Psychological aspect	Stress, fear of damage	Confidence, predictability of outcome

The long-term viability of any service model, particularly in the premium segment, is determined not by the number of one-off transactions but by the capacity to reliably reproduce customer loyalty. An examination of the Zelenska Beauty Blonde System demonstrates that loyalty in this case is a natural consequence of its system architecture.

CONCLUSION

The conducted study demonstrates that chemical damage to hair during lightening has a progressive, cumulative character, whose core is the irreversible oxidative modification of keratin disulfide bonds. This mechanism causes a pronounced decrease in mechanical endurance and destabilization of the structural integrity of the hair shaft. Common protocols that involve frequent application of aggressive procedures intensify this dynamic, creating a self-perpetuating cycle of injury accumulation.

The proposed hypothesis that the systemic integrative methodology implemented in the Zelenska Beauty Blonde System effectively counteracts this process has been confirmed. The combination of fundamental biochemical principles aimed at reducing chemical load with a client-centered mentoring model ensures a substantial reduction in cumulative traumatization, a sustained improvement in the long-term quality of hair, and the simultaneous fulfillment of key psychological demands of the contemporary consumer — for expertise, personalization, and risk reduction. A pivotal element of the strategy is extending the intervals between baseline lightening sessions to 5–6 months, which is directly associated with preserving hair health.

The practical significance of the work lies in positioning the Zelenska Beauty Blonde System as a reproducible, scientifically validated model for the premium segment of the cosmetology industry. The methodology provides practitioners with a clear algorithm for transitioning from transactional service to long-term client accompaniment, which makes it possible to achieve high and stable aesthetic outcomes while simultaneously building durable loyalty based on trust, predictability, and quantitatively measurable improvement in hair quality. Under conditions of intense competition and growing consumer awareness, the implementation of such a systemic methodology becomes a strategic advantage that ensures long-term commercial sustainability.

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