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Article

Hydrolyzed Keratin Hair Serum and Fiber Surface Quality: Formulation Performance, Smoothness, Shine, and Manageability Evidence

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Abstract: Hair smoothness, shine and manageability are surface-dominated cosmetic outcomes that depend on cuticle topography, friction, water balance and the deposition of conditioning materials. This study evaluates a leave-on serum containing 5.00% standardized hydrolyzed keratin (87.0% total peptides; weight-average molecular weight 1.7 kDa) together with 5.00% 1,3-propanediol, 3.00% glycerin, 2.00% betaine, 0.50% panthenol and 0.30% pullulan. The finished formulation remained macroscopically stable after centrifugation and three -5°C/25°C temperature cycles, with pH changing from 5.47 to 5.44. Literature evidence shows that hydrolyzed keratin can deposit on cuticle surfaces, partly penetrate damaged fibers, reduce water loss, preserve a smoother morphology and improve softness or brightness in hair models. Complementary studies link panthenol-containing leave-on technology with increased fiber diameter and demonstrate that hair shine and combing behavior are strongly governed by cuticle geometry, surface deposits and friction. The combined formulation-performance and published-evidence framework supports a plausible role for the serum in improving surface quality, tactile smoothness and manageability, while identifying objective optical, frictional and combing endpoints for subsequent formulation-specific testing.

Keywords: *hydrolyzed keratin; hair surface; shine; smoothness; combability; friction; panthenol; film forming*.

1. Introduction

Consumers perceive healthy hair largely through surface-dependent attributes: smooth touch, controlled friction, coherent shine, low frizz and easy combing [1]-[3]. Natural ageing, cleansing, heat, ultraviolet radiation and chemical treatments progressively erode cuticular structure, remove surface lipids and increase roughness [4][5]. These changes alter both the way light is reflected from the fiber and the mechanical energy required for hair-on-hair and comb-on-hair sliding.

Keratin-derived peptides are particularly relevant to surface repair because they can combine cuticular substantivity with partial penetration into damaged fibers [6][7]. Modern protein-based cosmetic research therefore increasingly treats hair care as a spatial problem: high-affinity deposits can regularize the surface, while smaller peptides may access subsurface regions and support mechanical integrity [7]-[9].

The serum evaluated here contains 5.00% standardized narrow-molecular-weight hydrolyzed keratin in a matrix that also includes panthenol, betaine, glycerin, 1,3-propanediol and pullulan. Within the TIMEFLYS hair-care portfolio, this architecture was selected to couple peptide deposition with humectancy, conditioning and film formation. The aim of the present evidence synthesis is to relate the measured formulation characteristics to published mechanisms and objective methods relevant to smoothness, shine, body and manageability.

2. Materials and Methods

2.1 Formulation architecture

The finished leave-on serum contained 5.00% hydrolyzed keratin, 5.00% 1,3-propanediol, 3.00% glycerin, 2.00% betaine, 0.50% panthenol, 0.30% pullulan, 0.25% hydroxyethyl cellulose, preservative, buffer and purified water. Hydrolyzed keratin was added below 35°C after hydration of the rheology and film-forming components, and the finished product was adjusted to pH 5.0-5.8 before deaeration and filling.

Table 1. Composition of the hydrolyzed-keratin hair-care serum

Component	Mass %	Function
Narrow-MW hydrolyzed keratin	5.00	Core hair-fiber active
Glycerin	3.00	Humectant
1,3-Propanediol	5.00	Moisturizing solvent
Betaine	2.00	Scalp/hair-fiber conditioning
Panthenol	0.50	Hair-fiber conditioning
Hydroxyethyl cellulose	0.25	Rheology modifier
Pullulan	0.30	Film former
Phenoxyethanol/ethylhexylglycerin (9:1)	0.80	Microbial control
Citric acid/sodium citrate buffer (1:2)	0.15	pH adjustment
Purified water	83.00	Continuous phase

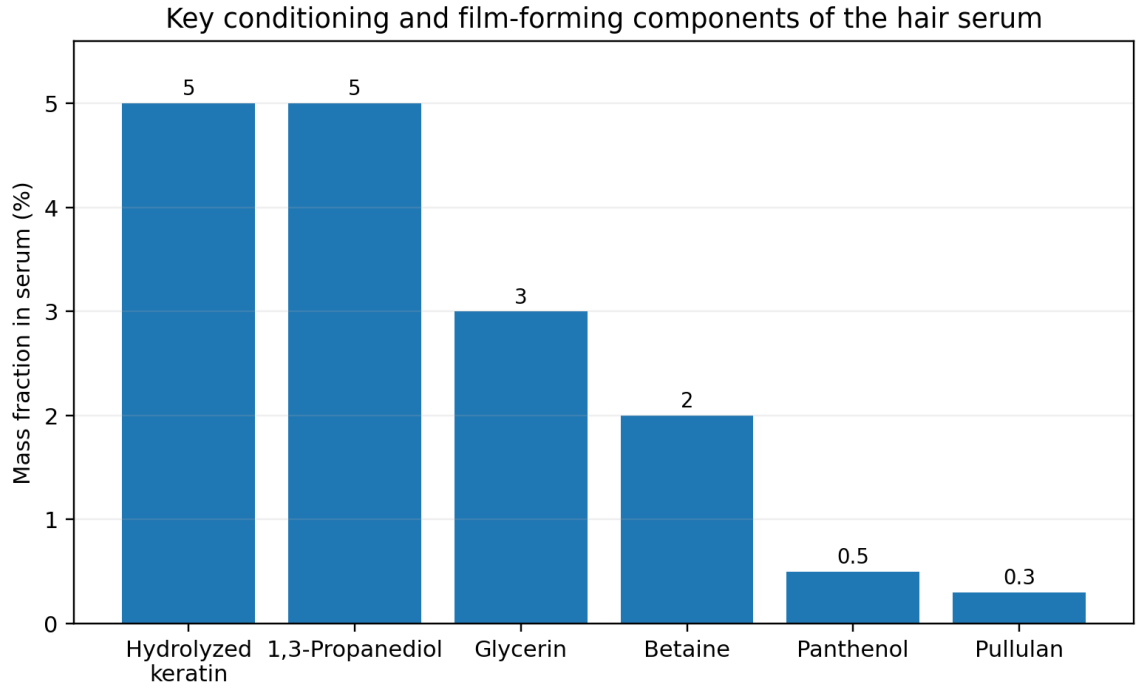

Figure 1. Key conditioning, humectant and film-forming components of the serum.

2.2 Formulation stability

Physical stability was evaluated after centrifugation at 3000×g for 30 min and three cycles between -5°C and 25°C. Macroscopic phase separation, irreversible precipitation, substantial crystallization and pH drift were used as formulation-state indicators.

2.3 Evidence selection and endpoint framework

The evidence framework emphasized human-hair studies of keratin peptides, conditioners and leave-on technologies, together with instrumental literature on hair shine, laser scattering, friction and combability [6]-[20]. Because surface appearance is not adequately represented by a single endpoint, the discussion integrates morphology, friction/tribology, combing force, fiber diameter, water loss and optical reflection.

3. Results

3.1 Stable delivery matrix

The finished serum showed no visually observable phase separation, irreversible precipitation or substantial crystallization after centrifugation and temperature cycling. pH changed from 5.47 to 5.44, remaining within the 5.0-5.8 target range. This physical stability is important for a leave-on product whose surface effects depend on reproducible deposition of peptides, humectants and film formers.

3.2 Published evidence for deposition, smoothness and water management

The 1.7 kDa hydrolyzed keratin falls in a molecular-weight region compatible with both penetration and surface interaction. Malinauskyte et al. showed that low- and mid-molecular-weight hydrolyzed keratins can penetrate into relaxed textured hair, while higher-molecular-weight fractions display greater surface substantivity; the different fractions produced measurable changes in mechanical properties [6]. A keratin-based repair system described by Liu et al. reduced water loss and produced softer, brighter repaired fibers [8].

Fan et al. used scanning electron microscopy and penetration experiments to show hydrolyzed keratin deposition on cuticle surfaces and partial entry into the cortex. After UV exposure, treated hair retained a smoother, healthier morphology than untreated fibers [9]. Together, these findings support a two-location model in which part of the peptide population participates in surface-film formation while smaller components can access subsurface damage.

3.3 Published evidence for manageability, body and optical appearance

Table 2. Representative evidence relevant to smoothness, shine and manageability

Study	Model/design	Key finding	Relevance
Malinauskyte et al. [6]	Hydrolyzed keratin, different MW	Low/mid-MW keratins penetrated;	Supports combined deposition/penetratio

		higher-MW fractions showed surface substantivity and mechanical benefits.	n model.
Liu et al. [8]	Keratin-based repair system	Reduced water loss and improved softness and brightness after repair treatment.	Directly relevant to sensory surface outcomes.
Fan et al. [9]	Hydrolyzed keratin under UV	SEM showed a surface film and smoother morphology after UV exposure.	Supports protective film and surface regularization.
da Gama et al. [10]	Conditioner agents after oxidative dyeing	Conditioning systems improved wet/dry combability and reduced hair damage.	Links surface conditioning with manageability.
Davis et al. [11]	Leave-on cosmetic technology	Panthenol-containing technology increased individual fiber diameter and modified mechanical behavior.	Supports panthenol contribution to body/fullness.
Gao et al. [12]; Puccetti & Kulcsar [13]	Optical/surface measurement studies	Shine and surface smoothness track cuticle geometry and deposits measurable by imaging/laser scattering.	Provides objective endpoints for future formulation-specific testing.
Weiand et al. [15]; Konno et al. [18]	Hair tribology	Friction is strongly governed by cuticle topography, surface chemistry, hair shape and conditioning deposits.	Mechanistic basis for combability and tactile smoothness.

Conditioning studies reinforce the importance of the complete matrix. In oxidatively dyed hair, conditioner agents including panthenol- and hydrolyzed-protein-containing systems improved wet and dry combability and reduced protein loss [10]. Davis et al. showed that a panthenol-containing leave-on technology could increase the diameter of individual terminal fibers and modify mechanical behavior, providing an experimentally grounded pathway to greater body and fullness [11].

Shine is governed by surface geometry and the balance between specular and diffuse reflection. Instrumental work by Gao et al. and Puccetti and Kulcsar demonstrated that conditioner deposits and cuticle inclination can be quantified through imaging and laser scattering [12][13]. Hair friction is similarly sensitive to cuticle condition, surface lipids, damage and conditioning deposits [15][18]. These studies define practical endpoints for future direct testing of the present serum: surface-angle distribution, directional friction, wet/dry combing force and standardized luster metrics.

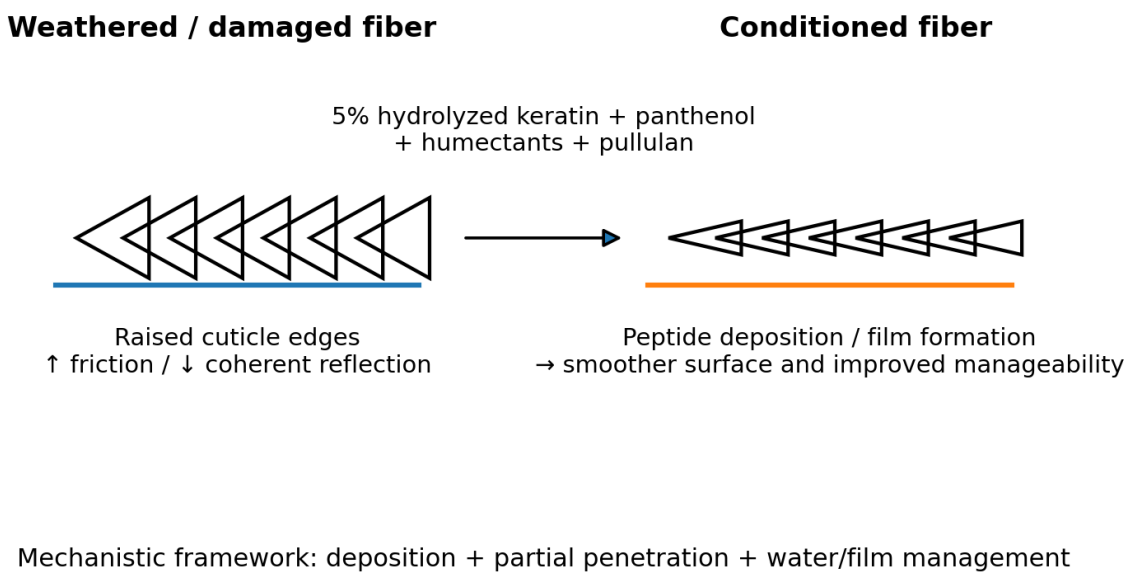

Figure 2. Mechanistic framework linking peptide deposition, partial penetration and film/humectant management with surface quality and manageability.

4. Discussion

4.1 Cuticle topology, friction and shine

Cuticle edges create directional anisotropy: friction rises when surfaces become rough, when the protective lipid layer is lost, or when raised cuticles interlock [15][18]. The same topographic disruption increases diffuse scattering and lowers coherent luster [12][13][17]. A useful hair-surface formulation therefore does not need to permanently reconstruct the biological cuticle; transient deposition that regularizes the outer surface, reduces inter-fiber friction and limits further wear can provide cosmetically meaningful benefit.

4.2 Why a peptide-rich 1.7 kDa material is relevant to surface quality

Hydrolyzed keratin can act across more than one spatial compartment. Low-to-mid molecular weights favor access to damaged regions, whereas larger peptide fractions or peptide aggregates can remain on the surface [6]-[9]. The standardized powder evaluated here contains 87.0% total peptides with only 9.3% free amino acids, favoring a peptide-dominant deposition profile. This is distinct from a simple amino-acid humectant solution and is mechanistically consistent with the published substantivity and repair literature.

4.3 Complementary role of panthenol, humectants and pullulan

The serum pairs keratin peptides with panthenol, glycerin, propanediol, betaine and pullulan. Panthenol-containing leave-on technology can increase fiber diameter and influence mechanical behavior [11], while humectants modulate water activity and fiber flexibility. Pullulan contributes a film-forming phase that may assist uniform deposition and tactile continuity. Protein derivatives with strong substantivity have also been associated with luster, smoothness and combability improvements in cosmetic testing [14]. These complementary mechanisms allow the complete formulation to target sensory appearance without relying on a single ingredient pathway.

4.4 Objective endpoints for future formulation-specific assessment

A high-quality evaluation program should separate closely related but non-identical attributes. Smoothness can be assessed by surface imaging and friction; manageability by wet/dry combing force; body by fiber diameter and bending behavior; shine by directional reflection or laser-scattering metrics [12][13][15][17][18]. Established mechanical-test frameworks [19][20] and controlled real-use wash-frequency protocols [16] provide complementary approaches for linking laboratory endpoints with routine hair condition. Real-use wash-cycle studies can then determine persistence. The stable TIMEFLYS serum provides a consistent formulation state from which these endpoint-specific studies can proceed.

5. Research Scope and Future Directions

The present investigation focuses on formulation composition, stability and mechanistically relevant published hair-fiber evidence. Subsequent work can directly quantify cuticle roughness, coefficient of friction, wet and dry combing force, standardized luster, fiber diameter and consumer sensory scoring after controlled wash cycles. Stratification by virgin, bleached, dyed and heat-damaged hair would help identify the conditions in which peptide deposition and humectant/film-former support provide the greatest benefit.

6. Conclusion

A physically stable leave-on serum combining 5% narrow-molecular-weight hydrolyzed keratin with panthenol, humectants and pullulan provides a coherent platform for improving hair-surface quality. Published studies support keratin peptide deposition, partial penetration, reduced water loss, smoother morphology and improved softness or brightness, while independent optical and tribological literature links cuticle condition to shine, friction and combability. These convergent lines of evidence support further direct testing of the formulation with objective smoothness, shine, friction and manageability endpoints.

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