

**LACTOBIONIC ACID: A MULTIFUNCTIONAL POLYHYDROXY ACID IN
DERMATOLOGY AND BIOMEDICAL APPLICATIONS**

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ABSTRACT

Lactobionic acid (LBA) is a polyhydroxy acid (PHA) derived from the oxidation of lactose, comprising galactose and gluconic acid units. Its unique combination of exfoliating, moisturizing, antioxidant, and chelating properties, coupled with excellent biocompatibility, has garnered significant attention in dermatology, cosmetics, and biomedical fields. This review delves into the chemical structure, mechanisms of action, and diverse applications of LBA, highlighting its potential in skin care, organ preservation, drug delivery, and food technology.

KEYWORDS: LBA, PHAs, Metalloproteinases, Dry Eye Syndrome.**1. INTRODUCTION**

The quest for effective yet gentle exfoliating agents has led to the emergence of polyhydroxy acids (PHAs) as favorable alternatives to alpha-hydroxy acids (AHAs). Among PHAs, lactobionic acid (LBA) stands out due to its exceptional moisturizing and antioxidant properties, coupled with minimal irritation potential.^[1,2] Beyond skincare, LBA's chelating and bioactive characteristics have found utility in organ preservation and pharmaceutical applications.^[3,4]

2. Chemical Structure and Properties

Lactobionic acid is synthesized through the oxidation of lactose, resulting in a disaccharide composed of galactose and gluconic acid linked via an ether bond. Its molecular formula is $C_{12}H_{22}O_{12}$, with a molecular weight of approximately 358.30 g/mol.^[5] The presence of multiple hydroxyl groups imparts strong hydrophilicity, enabling effective moisture retention and chelation of metal ions such as iron and copper.^[6,7]

3. Mechanisms of Action**3.1 Skin Benefits**

LBA functions as a gentle exfoliant, humectant, and antioxidant. Its larger molecular size compared to AHAs limits skin penetration, reducing irritation and making it suitable for sensitive or rosacea-prone skin. Clinical

studies have demonstrated its efficacy in improving skin hydration and elasticity without causing irritation.^[8,9]

3.2 Antioxidant and Chelation Activity

LBA exhibits potent antioxidant properties, scavenging reactive oxygen species (ROS) and inhibiting matrix metalloproteinases (MMPs), thereby preventing collagen degradation.^[10] Its chelating ability further mitigates oxidative stress by binding transition metals. In vitro studies have confirmed its capacity to reduce oxidative damage in cellular models.^[11]

3.3 Wound Healing and Tissue Protection

Studies have demonstrated LBA's efficacy in promoting wound healing by enhancing hydration and reducing inflammation. Additionally, its antioxidant properties contribute to tissue protection during organ preservation. LBA has been incorporated into organ preservation solutions, such as the University of Wisconsin (UW) solution, to prevent cell swelling and oxidative damage during transplantation.^[12,13]

4. Applications**4.1 Dermatology and Cosmetics**

- **Anti-aging Products:** LBA improves skin texture, elasticity, and tone, making it a valuable component in anti-aging formulations.^[14,15]

- **Sensitive Skin Care:** Its gentle nature makes it ideal for individuals with conditions like eczema and rosacea.^[16]
- **Post-procedure Care:** LBA aids in recovery following chemical peels or laser treatments by promoting hydration and reducing irritation.^[17]

4.2 Biomedical Applications

- **Organ Preservation:** LBA is utilized in organ storage solutions to prevent cell swelling and oxidative damage during transplantation.^[12,18]
- **Pharmaceutical Formulations:** Its chelating and stabilizing properties enhance the stability and efficacy of various drug formulations.^[19]
- **Wound Healing:** LBA's moisturizing and antioxidant effects contribute to accelerated wound healing and tissue regeneration.^[13]

4.3 Food and Nutraceuticals

LBA serves as a prebiotic, promoting the growth of beneficial gut bacteria. It is also used as a calcium carrier and antioxidant in functional foods.^[20] Recent studies have explored its role in enhancing the viability of probiotics during digestion.^[6]

4.4 Postmenopausal Dry Eye Syndrome and Lactobionic Acid

Postmenopausal women frequently experience dry eye syndrome (DES), a multifactorial disease characterized by tear film instability, inflammation, and ocular surface damage. Estrogen deficiency is implicated in the pathophysiology, affecting lacrimal and meibomian gland function and reducing tear production and quality.^[21,22]

Oxidative stress is increasingly recognized as a key contributor to DES, particularly in postmenopausal populations. Reduced estrogen levels correlate with increased reactive oxygen species (ROS) and pro-inflammatory cytokines in the lacrimal gland and ocular surface.^[23] As a potent antioxidant and metal chelator, lactobionic acid may offer therapeutic benefit by neutralizing ROS and reducing oxidative injury to ocular tissues.

Furthermore, LBA's strong humectant properties can potentially help restore tear film stability by increasing ocular surface hydration. Its large molecular size and polyhydroxy structure support prolonged retention on the ocular surface, suggesting utility in artificial tear formulations or ophthalmic gels.^[24]

Recent preclinical studies have demonstrated that polyhydroxy acids, including LBA, can protect corneal epithelial cells from oxidative damage and promote epithelial barrier integrity.^[25] While direct clinical trials are limited, these properties highlight lactobionic acid as a promising candidate for managing postmenopausal dry eye, particularly where conventional lubricants fall short.

5. Safety and Tolerability

Clinical studies have confirmed that LBA is non-toxic, non-sensitizing, and well-tolerated, even with prolonged use. Its minimal irritation potential makes it suitable for individuals with sensitive skin or those intolerant to AHAs. In vivo and in vitro assessments have demonstrated its safety profile in various formulations.^[2,8,10]

6. Future Directions

Emerging research is exploring LBA's potential in enhancing transdermal drug delivery, synergistic formulations with peptides and retinoids, and applications in ophthalmology and biomaterials. Nanoparticle-conjugated LBA is also under investigation for targeted drug delivery, particularly in hepatic systems due to its affinity for asialoglycoprotein receptors.^[7,19]

7. CONCLUSION

Lactobionic acid represents a significant advancement in both dermatological and biomedical sciences. Its unique combination of exfoliating, hydrating, antioxidant, and chelating properties, coupled with excellent tolerability, positions it as a versatile agent in various therapeutic and cosmetic applications. Continued research is anticipated to further elucidate its potential, solidifying LBA's role in innovative healthcare solutions.

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