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Short communication

Regenerative potential of liposomal CoQ10 in an *in vitro* burn wound model

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Introduction

Burn injuries represent a major clinical challenge due to prolonged inflammation, oxidative stress, microbial contamination and delayed tissue regeneration. Excessive production of reactive oxygen species (ROS) contributes significantly to cellular damage, collagen degradation and impaired wound healing, often resulting in chronic wounds and prolonged recovery (Wang et al., 2013). Therefore, development of advanced therapeutic systems capable of providing antioxidant protection and regenerative support has become an important area of pharmaceutical and biomedical research.

Coenzyme Q10 (CoQ10) is a naturally occurring lipophilic antioxidant involved in mitochondrial energy production, membrane stabilization and cellular protection against oxidative damage. In addition to its antioxidant properties, CoQ10 exhibits anti-inflammatory and regenerative effects, making it a promising candidate for topical burn treatment (Schmelzer et al., 2008). However, its poor aqueous solubility and limited penetration through biological membranes significantly reduce its therapeutic efficacy.

Liposomes are phospholipid-based nanocarriers widely investigated for topical drug delivery due to their biocompatibility, ability to improve local bioavailability and controlled release properties (Akbarzadeh et al., 2013). Encapsulation of CoQ10 into liposomal systems may therefore improve its antioxidant and regenerative activity while enhancing interaction with damaged skin tissue.

Therefore, the aim of this study was to evaluate the regenerative and protective effects of liposomes with encapsulated CoQ10 on human dermal fibroblasts under oxidative stress conditions.

Materials and methods

The following materials were used for the study: soy lecithin (Vitalija, N. Macedonia), LIPOID PE 18:0/18:0-PEG 2000 (Lipoid, Germany), cholesterol (Sigma Aldrich, USA), chloroform and methanol (Merck, Germany), Tween 80 (Sigma-Aldrich, Germany) and CoQ10 donated by Omni Medical, N. Macedonia. Human dermal fibroblast (HDF) cell lines obtained from the cell bank of the Faculty of Pharmacy, Ss. Cyril and Methodius University in Skopje were used for biological investigations.

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CoQ10-loaded and empty liposomes were prepared using the thin-film hydration method followed by homogenization (Shalabalija et al., 2021). Phospholipids, cholesterol and CoQ10 were dissolved in a methanol/chloroform mixture, followed by solvent evaporation to obtain a thin lipid film. Hydration with phosphate buffer pH 7.4 produced liposomal dispersions which were subsequently homogenized and stored under refrigerated conditions

Regenerative activity was evaluated using an *in vitro* wound-healing model on fibroblast monolayers. The *in vitro* scratch assay represents a widely accepted model for evaluation of fibroblast migration and regenerative potential during wound healing (Liang et al., 2007). Oxidative stress was induced using H_2O_2, which is commonly employed as an experimental model for investigation of antioxidant and cytoprotective effects in fibroblast cultures (Wang et al., 2013). Following oxidative stress induction, fibroblasts were treated with empty and CoQ10-loaded liposomal formulations. Lesion closure after 24 h incubation was evaluated microscopically using ImageJ software (Image processing and analysis in Java).

Results and discussion

The obtained results demonstrated significant protective and regenerative effects of CoQ10-loaded liposomes. Following oxidative stress induction, treated fibroblasts showed improved viability (38–104%) compared with untreated cells and empty liposomes, depending on formulation concentration and treatment conditions. Empty liposomes also demonstrated moderate protective effects, most likely due to antioxidant phospholipids originating from soy lecithin.

Additionally, a positive correlation between formulation concentration and percentage of metabolically active cells was observed, indicating concentration-dependent antioxidant protection. The regenerative activity investigations confirmed significant wound-healing potential of the developed formulation. After 24 h of treatment, CoQ10-loaded liposomes reduced the induced lesion area by 74.25%, while empty liposomes reduced lesion size by 55.87%. In comparison, untreated controls demonstrated only 19.22% lesion reduction. Microscopic analysis confirmed enhanced fibroblast migration and accelerated wound closure in the presence of CoQ10-loaded liposomes. Similar antioxidant and protective effects of CoQ10-loaded liposomal systems have previously been reported by Gokce et al. (2012). The superior regenerative activity observed for CoQ10-loaded liposomes may be associated with sustained release of CoQ10 from liposomal carriers and improved interaction between phospholipid vesicles and cellular membranes. Such systems may therefore provide favorable microenvironmental conditions for tissue regeneration and recovery after oxidative injury.

Conclusion

The developed liposomal CoQ10 formulation demonstrated significant antioxidant and regenerative activity on fibroblast cell lines. Encapsulation of CoQ10 improved cellular protection against oxidative stress and accelerated wound closure in vitro, suggesting promising potential for topical burn wound treatment and chronic wound healing.

References

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