Evidence that the marine-derived multi-mineral Aquamin has anti-inflammatory effects on cortical glial-enriched cultures.

Sinead Ryan, Denise O'Gorman, Yvonne Nolan

▶ **To cite this version:**

Sinead Ryan, Denise O'Gorman, Yvonne Nolan. Evidence that the marine-derived multi-mineral Aquamin has anti-inflammatory effects on cortical glial-enriched cultures.. Phytotherapy Research, Wiley, 2010, 10.1002/ptr.3309 . hal-00599843

HAL Id: hal-00599843

https://hal.archives-ouvertes.fr/hal-00599843

Submitted on 11 Jun 2011

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Evidence that the marine-derived multi-mineral Aquamin has anti-inflammatory effects on cortical glial-enriched cultures.

Journal:	*Phytotherapy Research*
Manuscript ID:	PTR-10-0614.R1
Wiley - Manuscript type:	Short Communication
Date Submitted by the Author:	18-Aug-2010
Complete List of Authors:	Ryan, Sinead; University College Cork, Anatomy and Neuroscience O'Gorman, Denise; Marigot Limited Nolan, Yvonne; University College Cork, Anatomy and Neuroscience
Keyword:	inflammation, Aquamin, IL-1beta, TNFalpha, glia, brain

SCHOLARONE™
Manuscripts

For Review

Evidence that the marine-derived multi-mineral Aquamin has anti-inflammatory effects on cortical glial-enriched cultures.

Sinead Ryan[1], Denise M. O'Gorman[2], Yvonne M. Nolan[1*]

[1]Department of Anatomy and Neuroscience, University College Cork, Ireland

[2]Marigot Limited, Strand Farm, Currabinny, Carrigaline, Co Cork, Ireland

*__Corresponding author:__ Yvonne M. Nolan, Department of Anatomy and Neuroscience, University College Cork, Ireland

Tel: 353 (0)21 4902787, Fax: 353 21 4273518 email: y.nolan@ucc.ie

Short Title: Anti-inflammatory properties of Aquamin in cortical glia

Key words: Inflammation; Aquamin, glia, TNFα, IL-1β, brain

This work was funded by Marigot Ltd. There are no conflicts of interest.

For Peer Review

Abstract

It is well established that neuroinflammation contributes to brain aging, and that cortical cells are particularly vulnerable. Lipopolysaccharide stimulates the release of the pro-inflammatory cytokines, tumor necrosis factor-alpha and interleukin-1beta from glial cells which consequently induces an impairment in neuronal cell function. The food supplement Aquamin is a natural, multi-mineral derived from the red algae *Lithothamnion corallioides*, rich in calcium, magnesium and 72 other trace minerals. The aim of this study was to evaluate the anti-inflammatory potential of Aquamin in lipopolysaccharide-stimulated, glial-enriched primary cultures of rat cortex. We report that Aquamin prevented lipopolysaccharide-induced secretion of tumor necrosis factor-alpha and interleukin-1beta from cortical glia. These data suggest that nutritional supplements such as Aquamin may play an important role in impeding the detrimental effects of excessive inflammation in the brain.

Introduction

Minerals such as magnesium copper, zinc, manganese and selenium are now recognized as important regulators of inflammation and growing evidence suggests that mineral-rich seaweed extracts may play an important role in the regulation of inflammation (Granert *et al*., 1999; Jung *et al*., 2007). The food supplement, Aquamin is a natural seaweed-derived multi-mineral from the red algae *Lithothamnion corallioides* which is rich in calcium, magnesium and trace amounts of other minerals (Table 1). It has recently been shown to provide relief from the symptoms of osteoarthritis (Frestedt *et*

For Peer Review

al., 2009) and to be of benefit in digestive and bone health (Aslam *et al*., 2010a; Aslam *et al*., 2010b).

It is well established that inflammation contributes to cortical neuronal dysfunction in age-related neurological diseases such as Alzheimer's disease, amyotrophic lateral sclerosis, multiple sclerosis and Parkinson's disease (Minghetti, 2005). Microglia are considered the resident immune cells of the brain and along with astrocytes, constitute the major glial cell types. Under conditions such as neurodegenerative disease, injury, exposure to environmental toxins, infection or age, microglia become activated to release large numbers of mediators such as cytokines and free radicals. Microglial-secreted pro-inflammatory cytokines such as interleukin-1 beta (IL-1β) and tumor necrosis factor alpha (TNFα) can influence neurons and their ability to process information and can ultimately contribute to neuronal cell death. Astrocytes provide structural and metabolic support to neurons and also play a role in brain inflammation through antigen presentation and cytokine secretion. It has previously been reported that exposure to the endotoxin lipopolysaccharide (LPS) induces release of IL-1β and TNFα from cortical glia to contribute to neuronal degeneration (Long-Smith *et al*., 2010). The present study was designed to investigate the anti-inflammatory potential of Aquamin in LPS-stimulated, glial-enriched rat cortical cultures to determine if nutritional supplements, such as Aquamin, may play a role in impeding the detrimental effects of excessive inflammation in the brain.

Materials and Methods

For Peer Review

Aquamin (Food and Drug Administration (FDA) GRAS 000028) was prepared from the mineral-rich red marine algae, *Lithothamnion corallioides* harvested off the Atlantic coasts of Ireland and Iceland under approved licenses. The calcified seaweed was separated from extraneous materials, sterilized, dried and milled under ISO and HACCP certification. Approximately 0.5mg/ml of Aquamin is equivalent to a physiological level of extracellular Ca^{2+}. The concentrations of Aquamin were determined from previous experiments using low passage human dermal fibroblasts, calcium sensitive and calcium resistant colon carcinoma cell lines (CBS, Moser, Fet, HCT-116 and SW480) (Aslam *et al.,* 2009), the murine macrophage cell line RAW 264.7, and the pre-osteoblastic cell line MC3T3-E1 (unpublished data). Aquamin demonstrated no signs of toxicity at any of the concentrations used in the current study. Glial-enriched cultures were prepared from cortical tissue isolated from seven separate postnatal day 2 Sprague-Dawley rat pups (Biological Services Unit, University College Cork) as previously described (Long-Smith *et al*., 2010). All scientific procedures were performed under a license issued by the Department of Health and Children (Ireland) and in accordance with the European Communities Council Directive (86/609/EEC). After 7-10 days *in vitro* (DIV), glia were incubated in the presence or absence of LPS (50 ng/ml) and Aquamin (0.05, 0.1, 0.5, 1 and 2 mg/ml). Twenty-four hours later, supernatant was removed for analysis of TNFα and IL-1β by ELISA (R&D Systems, UK). Untreated culture media was used as a control. The cells were assessed for morphological signs of apoptosis and necrosis (loss of cell membrane asymmetry and attachment, cell shrinkage, cell blebbing, nuclear fragmentation and chromatin condensation) prior to, during and after 24 hours incubation with Aquamin. All cells were considered viable throughout the experiment. ANOVA with *post hoc* Student Newman-Keuls was used to

For Peer Review

determine which conditions were significantly different from each other. Results were expressed as means with standard error of the mean (SEM) and deemed significant when $p<0.05$.

Results and Discussion

The data presented demonstrate that LPS induced a significant increase in TNFα (Figure 1A) and IL-1β (Figure 1B) secretion from glial-enriched cortical cultures 24 hours after LPS treatment ($p<0.001$). Treatment with all doses of Aquamin significantly attenuated the LPS-induced increase in TNFα and IL-1β secretion ($p<0.01$). Analysis of extracellular concentrations of TNFα revealed that Aquamin prevented its release from LPS-stimulated cortical glial cells in a dose-dependent manner and that all doses of Aquamin significantly attenuated the LPS-induced release of IL-1β. These data suggest that the anti-inflammatory effects of Aquamin may be reliant on blockade of the pro-inflammatory effects of both TNFα and IL-1β.

Seaweed extracts have previously been reported to inhibit pro-inflammatory cytokine release. Fucoidans from brown algae have been shown to inhibit TNF-α and IL-1 production in cerebrospinal fluid in a rabbit meningitis model (Granert *et al*., 1999) and an extract from the seaweed Hizikia fusiform reduced TNFα production in LPS-stimulated murine microglial cells (Jung *et al*., 2007). Aquamin is a seaweed-derived multi-mineral rich in calcium and magnesium. It has been shown that IL-1β reduced Ca2+ channel activity and influx in rat cortical neurons (MacManus *et al*., 2000) suggesting that Ca2+ supplementation may be beneficial in situations of excessive IL-

For Peer Review

1β concentration in the brain such as occurs with aging. Increased magnesium in the diet may influence inflammation through reducing the serum level of the pro-inflammatory C-reactive protein. Copper, zinc and manganese are essential cofactors of the antioxidant enzyme superoxide dismutase and selenium is a vital constituent of the antioxidant glutathione peroxidase. A compromised antioxidant defense has been observed in the cortex of aged rats in parallel with increased IL-1β concentration (McGahon *et al*., 1999). Accumulation of reactive oxygen species in the rat cortex and hippocampus has been demonstrated after LPS treatment (Nolan *et al*., 2003) while an antioxidant-enriched diet has been shown to reverse age-related and inflammatory-induced neuronal deficits (McGahon *et al*., 1999). Consequently, many of the antioxidant-related minerals that compose Aquamin may be anti-inflammatory and may directly or indirectly have neuroprotective properties.

The current study provides clear evidence that Aquamin exerts anti-inflammatory effects by preventing LPS-induced TNFα and IL-1β release from rat cortical glia. This evidence for an anti-neuroinflammatory activity of the food supplement Aquamin may have significant implications for brain health

For Peer Review

References

Aslam MN, Bhagavathula N, Paruchuri T, Hu X, Chakrabarty S, Varani J. 2009. Growth-inhibitory effects of a mineralised extract from the red marine algae, Lithothamnion calcareum, on Ca2+,-sensitive and Ca2+-resistant human colon carcinoma cells. *Cancer Letts* **283**: 186-192.

Aslam MN, Kreider JM, Paruchuri T, Bhagavathula N, DaSilva M, Zernicke RF, Goldstein SA, Varani J. 2010. A mineral-rich extract from the red marine algae Lithothamnion calcareum preserves bone structure and function in female mice on a Western-style diet. *Calcif Tissue Intl* **86**: 313-324.

Aslam MN, Paruchuri T, Bhagavathula N, Varani J. 2010. A mineral-rich red algae extract inhibits polyp formation and inflammation in the gastrointestinal tract of mice on a high-fat diet. *Integrat Cancer Ther* **9**: 93-99.

Frestedt JL, Kuskowski MA, Zenk JL. 2009. A natural seaweed derived mineral supplement (Aquamin F) for knee osteoarthritis: a randomised, placebo controlled pilot study *Nutr J* **8**:7-14.

Granert C, Raud J, Waage A, Lindquist L. 1999. Effects of polysaccharide fucoidin on cerebrospinal fluid interleukin-1 and tumor necrosis factor alpha in pneumococcal meningitis in the rabbit. *Infect Immun* **67**:2071-2074.

For Peer Review

Jung K, Ha E, Uhm Y, Park H, Kim MJ, Kim H, Baik H, Hong M, Yang J, Yim SV. 2007. Suppressive effect by Hizikia fusiforme on the production of tumor necrosis factor in BV2 murine microglial cells. *Neurol Res* **29** Suppl 1:S88-92.

Long-Smith CM, Collins L, Toulouse A, Sullivan AM, Nolan YM. 2010. Interleukin-1β contributes to dopaminergic neuronal death induced by lipopolysaccharide-stimulated rat glia in vitro. *J Neuroimmunol* In Press.

MacManus A, Ramsden M, Murray M, Henderson Z, Pearson HA, Campbell VA. 2000. Enhancement of (45)Ca(2+) influx and voltage-dependent Ca(2+) channel activity by beta-amyloid-(1-40) in rat cortical synaptosomes and cultured cortical neurons. Modulation by the proinflammatory cytokine interleukin-1beta. *J Biol Chem* **275**:4713-4718.

McGahon BM, Murray CA, Horrobin DF, Lynch MA. 1999. Age-related changes in oxidative mechanisms and LTP are reversed by dietary manipulation. *Neurobiol Aging* **20**: 643-653.

Minghetti L. 2005. Role of inflammation in neurodegenerative diseases. *Curr Opin Neurol* **18**:315-321.

Nolan Y, Vereker E, Lynch AM, Lynch MA. 2003. Evidence that lipopolysaccharide-induced cell death is mediated by accumulation of reactive oxygen species and activation of p38 in rat cortex and hippocampus. *Exp Neurol* **184**:794-804.

For Peer Review

Table 1: Typical Mineral Composition of Aquamin.

Mineral	Dry Salt Weight
Calcium	141,200ppm
Magnesium	18,580ppm
Phosphorous	436ppm
Potassium	81.5ppm
Sulphur	3620ppm
Iron	234ppm
Boron	8.45ppm
Sodium	1780ppm
Manganese	9.71ppm
Cobalt	<0.05ppm
Copper	0.191ppm
Zinc	10.7ppm
Selenium	1.75ppm

For Peer Review

Figure Legends:

Figure 1: Aquamin prevents LPS-induced release of TNFα and IL-1β. TNFα (A) and IL-1β (B) levels from LPS-stimulated glial-enriched cortical cultures. Data are expressed means ± SEM of seven independent experiments, each performed in triplicate. ***p<0.001 vs. control; ++p<0.01; +++p<0.001 vs. LPS (ANOVA).

For Peer Review

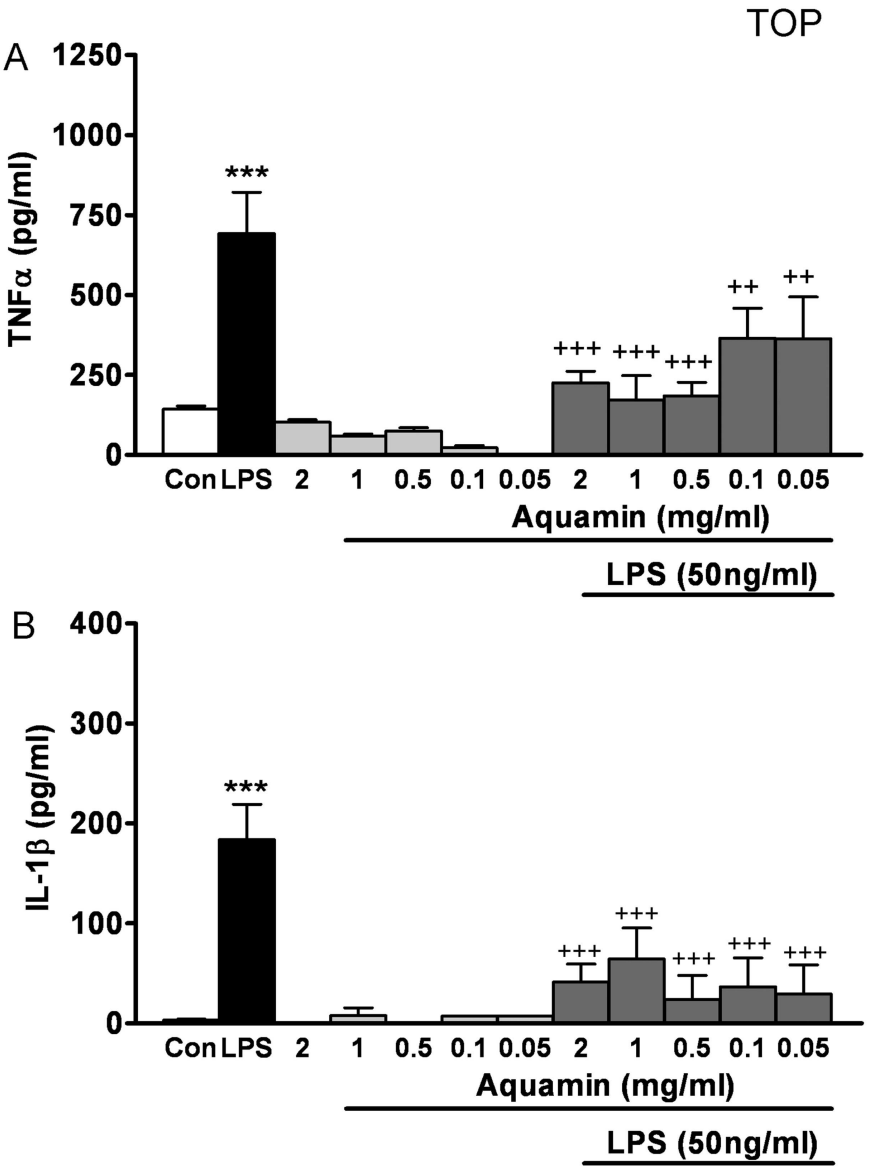

Figure 1: Aquamin prevents LPS-induced release of TNFα and IL-1β. TNFα (A) and IL-1β (B) levels from LPS-stimulated glial-enriched cortical cultures. Data are expressed means ± SEM of seven independent experiments, each performed in triplicate. ***p<0.001 vs. control; ++p<0.01; +++p<0.001 vs. LPS (ANOVA).
109x141mm (600 x 600 DPI)