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Glyceride-Type DHA-Enriched Schizochytrium Oil and Retinal Nutrition: Human Evidence Across Visual Development and Ocular Health

Bougrain Mouad¹, Patrick O'Neill², Hunter Blake³

^{1,2,3} National Standards Laboratory SA, Chemin des Orlons 10, CH-1860 Aigle, Switzerland

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Abstract: DHA is a major retinal membrane fatty acid, with the clearest supplementation evidence coming from periods of rapid visual development. We characterized a BCLC glyceride-type DHA-enriched Schizochytrium oil and compared its formulation profile with controlled human evidence on visual maturation and ocular endpoints. Representative batches contained 46.2-51.8% DHA and 93.4-95.1% glyceride components, with low free fatty acids, <0.2% fatty acid ethyl esters and controlled oxidation indices. Infant trials show that DHA supply can influence visual-acuity maturation in selected settings, whereas prenatal studies and later-life ocular trials are more heterogeneous. The formulation therefore provides a defined algal-DHA lipid matrix for ocular studies in which life stage and endpoint are specified in advance.

Keywords: *DHA; retina; visual acuity; Schizochytrium; photoreceptors; ocular nutrition; algal oil; glycerides*

1. Introduction

The retina is rich in DHA, especially in photoreceptor membranes. That structural role is most likely to be reflected clinically when DHA accretion is rapid or dietary supply is constrained. For this reason, term-infant, preterm, prenatal and later-life ocular trials should be read as separate evidence domains rather than pooled into a single claim.

BCLC is a non-fish Schizochytrium oil enriched to approximately 46-52% DHA while retaining >93% glyceride components. The process also limits oxidation of a highly unsaturated lipid. The translational question is whether a well-characterized glyceride DHA matrix can provide reproducible exposure for visual or ocular endpoints that are appropriate to the study population.

2. Materials and Methods

2.1 Formulation characterization

The DHA matrix was prepared under nitrogen at low temperature. A mild, low-degree enzymatic hydrolysis was followed by salted aqueous-ethanol deacidification, composite adsorption stabilization and one short-path distillation step. Fatty-acid composition, glyceride classes, free fatty acids, fatty acid ethyl esters, acid value, peroxide value and accelerated oxidation were measured in the final oil.

2.2 Visual and ocular evidence synthesis

Randomized or controlled studies were grouped as term-infant formula trials, preterm-neonatal trials, prenatal maternal supplementation and later-life ocular studies. Visual acuity, visual maturation, macular-disease progression and ocular-surface measures were treated as different outcomes. Algal-DHA bioavailability studies were used only to support exposure context.

3. Results

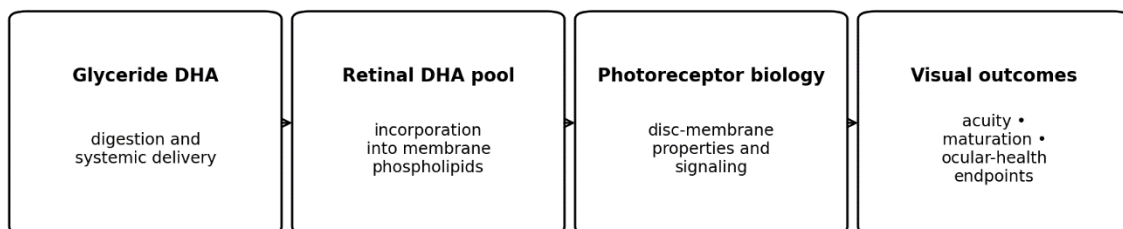
3.1 Composition and oxidative quality of the DHA matrix

Table 1. Representative composition of the BCLC glyceride-type DHA-enriched oil.

Sample	DHA %	C14:0+C16:0 %	Glycerides %	Acid value	PV	DHA recovery %	Yield %
Raw oil	39.2	37.6	98.2	1.4	3.0	—	—
Batch 1	48.6	24.8	94.6	1.1	1.5	94.8	76.5
Batch 2	46.2	27.5	95.1	1.3	1.7	97.3	80.0
Batch 3	51.8	21.2	93.4	1.5	1.8	91.0	72.0

The representative batches contained 46.2-51.8% DHA and 93.4-95.1% glyceride components. In the benchmark batch, peroxide value was 1.5 meq/kg and p-anisidine value 5.8; after 30 days at 40°C under light protection, the values were 3.8 meq/kg and 8.9. Fatty acid ethyl esters remained <0.2% in each batch.

DHA-centered pathway from oral lipid delivery to retinal function



Conceptual evidence map; clinical effects depend on life stage, baseline status, dose and endpoint selection.

Figure 1. Conceptual pathway linking oral glyceride DHA delivery to retinal phospholipid incorporation, photoreceptor biology and visual outcomes. Clinical effects are life-stage and endpoint dependent.

3.2 Human evidence for visual maturation and ocular outcomes

Table 2. Selected randomized human studies relevant to DHA and visual/ocular outcomes.

Study	Population	Exposure	Visual/ocular outcome
DIAMOND [1]	343 healthy term formula-fed infants	0, 0.32%, 0.64% or 0.96% DHA of total fatty acids	0.32% DHA improved visual-acuity maturation; higher concentrations did not show additional benefit
Smithers 2008 [2]	Preterm infants <33 wk gestation	~1% DHA vs ~0.3% DHA until expected due date	Higher-DHA regimen improved visual acuity at early corrected-age assessment
Smithers 2011 [3]	Pregnant women and term infants	Maternal DHA supplementation during pregnancy	No treatment difference in infant visual acuity at 4 mo
Judge 2007 [4]	Pregnant women; infant follow-up	DHA-containing functional food in pregnancy	Higher infant visual acuity at 4 mo but not 6 mo
AREDS2 [5]	Adults at risk of AMD progression	DHA+EPA added to AREDS formulation	No significant reduction in progression to advanced AMD from omega-3 addition

DIAMOND randomized 343 healthy term formula-fed infants to 0, 0.32%, 0.64% or 0.96% DHA of total fatty acids. The 0.32% condition improved visual-acuity maturation, with no additional visual gain at the higher concentrations [1]. In preterm infants, a regimen providing approximately 1% rather than approximately 0.3% DHA improved early visual-acuity measures [2].

Prenatal studies did not give a single pattern. Smithers et al. reported no difference in infant visual acuity at four months after maternal DHA supplementation [3]. Judge et al. observed better visual acuity at four months after a DHA-containing functional food, but the difference was not present at six months [4].

Later-life disease asks a different question. In AREDS2, adding DHA+EPA to the background AREDS formulation did not significantly reduce progression to advanced age-related macular degeneration [5]. That result is best interpreted within established AMD rather than as a test of DHA's structural role during retinal development.

Earlier infant studies help fill out the developmental sequence. DHA-enriched complementary food accelerated visual-acuity maturation in one term-infant study [6], and an earlier randomized trial supported the importance of DHA and arachidonic acid for term-infant acuity development [7]. For adult exposure, algal DHA has shown bioequivalence across different algal oils and food formats [8], and algal-oil capsules produced DHA exposure comparable with cooked salmon in a separate study [9].

The adult ocular literature is more heterogeneous. NAT2 tested DHA supplementation for prevention of exudative AMD [10], following the feasibility work in NAT-1 [11]. Randomized dry-eye studies have reported improvement in selected symptoms, tear-film stability or ocular-surface measures with omega-3 regimens containing DHA [12], [13], and a short VDT-user trial also reported symptomatic and tear-film changes [14]. By contrast, the large VITAL ancillary trial found no reduction in incident dry eye with long-term marine omega-3 supplementation [15].

4. Discussion

The visual-development data are most consistent when the population has a clear physiological reason for DHA demand. DIAMOND and the preterm trial both identified visual signals [1], [2], while the prenatal results were mixed [3], [4]. Earlier feeding studies also support the idea that developmental timing matters [6], [7].

Formulation quality remains relevant because DHA is easily oxidized. The BCLC oil entered storage with low peroxide and p-anisidine values and remained predominantly glyceridic. Human work with algal

oils shows that DHA can be delivered effectively from capsules and DHA-fortified foods [8] and can reach circulating pools at levels comparable with a fish source [9].

Later ocular outcomes should be kept separate from infant acuity. NAT2 evaluated DHA in patients at risk of exudative AMD [10], while the earlier NAT-1 study established feasibility of oral DHA supplementation in an AMD population [11]. Ocular-surface trials add another domain: fish-oil or omega-3 regimens containing DHA have improved selected dry-eye signs or symptoms in some randomized studies [12]-[14], whereas the large VITAL ancillary trial found no reduction in incident dry eye with long-term marine omega-3 supplementation [15]. The contrast is useful because treatment of existing symptoms and prevention of new disease are different endpoints.

5. Research Scope and Future Directions

A formulation-specific ocular study should select one physiological domain. Developmental work can focus on achieved DHA status and sensitive visual processing measures. Adult studies can instead test retinal or ocular-surface outcomes, but should not combine AMD progression, contrast sensitivity and dry-eye symptoms into one composite claim. Measuring the achieved omega-3 status would help connect the oil dose with the observed response.

6. Conclusion

The BCLC Schizochytrium oil combines high DHA density, a predominantly glyceride structure and controlled oxidative quality. Human evidence is strongest for visual maturation in selected developmental settings. Prenatal, AMD and dry-eye studies show why the life stage and endpoint must be defined before efficacy is judged. This formulation provides a suitable platform for that kind of targeted ocular-nutrition study.

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