Algal Research 50 (2020) 101998

Contents lists available at ScienceDirect

Algal Research

journal homepage: www.elsevier.com/locate/algal

Microalgae biomass as an additional ingredient of gluten-free bread: Dough rheology, texture quality and nutritional properties

Sheyma Khemiri[a,b,*], Nadia Khelifi[a,d], Maria Cristiana Nunes[b], Alice Ferreira[c], Luisa Gouveia[c], Issam Smaali[a], Anabela Raymundo[b]

[a] University of Carthage, INSAT, Laboratory of Protein Engineering and Bioactive Molecules (LR11ES24), BP 676, 1080 Cedex, Tunisia
[b] LEAF – Linking Landscape, Environment, Agriculture and Food, Instituto Superior de Agronomia, Universidade de Lisboa, Tapada da Ajuda, 2p Lisboa, Portugal
[c] LNEG-UB National Laboratory of Energy and Geology/Bioenergy Unit, Estrada do Paço do Lumiar 22, 1649-038 Lisboa, Portugal
[d] University of Carthage, Higher Institute of Fisheries and Aquaculture, BP 15, Errimel, 20 7080 Bizerte, Tunisia

ARTICLE INFO

Keywords:
Microalgae
Functional ingredients
Gluten-free bread
Physicochemical properties
Mixing properties
Sensory evaluation

ABSTRACT

Microalgae have been widely used as a source of functional ingredients such as pigments, antioxidants, vitamins, and omega-3 polyunsaturated fatty acids. They also represent a promising alternative source of protein. The objective of this study was to evaluate the impact of the addition of two green microalgae species (*Nannochloropsis gaditana* L2 and *Chlamydomonas* sp. EL5) on the techno-functional and nutritional properties of gluten-free bread. Microalgae biomass was added in the amounts of 1.0 and 3.0 g/100 g of flour. The behavior of the dough during the mixing as well as the physicochemical properties of the prepared breads were investigated. Gluten-free bread with *N. gaditana* L2 and *Chlamydomonas* sp. EL5 presented significantly higher protein and higher levels of lipids and ash, compared with the control bread. The incorporation of 3% microalgae biomass revealed a 100% increase in iron and calcium contents. The fatty acid profile of supplemented bread changed in a species-specific manner with a particular increase in linolenic acid (18:3 ω3) and a decrease in ω3/ω6 ratio. Besides, due to its original biochemical composition, mainly the highly protein content, microalgae incorporation was found to bring an overall structuring effect on the gluten-free bread texture. However, the dough mixing properties were not affected significantly by microalgae addition. A significant change in color was recorded in doughs, breads, crusts and crumbs. This was caused by the presence of pigment in microalgae biomass, which turned into more intense green-yellow tonalities. A sensory analysis revealed that the supplemented breads scored highest for nearly all the sensory parameters with the 3% *N. gaditana* L2 bread as the preferred one in terms of global appreciation. This innovative approach gives new insights of the possibility of improving gluten-free products, structurally and nutritionally, using only microalgae as a natural and a sustainable food ingredient.

1. Introduction

Gluten is a complex mixture of insoluble proteins comprising the gliadins and glutenins in wheat and equivalent proteins in barley and rye. Gluten is responsible for the viscoelastic behavior of the dough and the chewiness of foods made from wheat flour [21]. Recently, the gluten-free products market has registered a remarkable growth driven by the rapid rise of the global incidence of pathologies related to gluten intake, namely wheat allergy, celiac disease, and non-celiac gluten sensitivity, combined with the growing belief that gluten-free products are associated with a healthier life style [10,50]. In all cases, a lifelong gluten-free diet is the only treatment currently available [40]. Thus, a gluten-free product with a good sensory and nutritional quality remains the biggest wish of individuals with gluten disorders. Gluten-free bread, more than any other gluten-free product, has received a lot of attention from researchers and food technologists. Some recent studies have investigated techniques that can improve the characteristics of the final product [32]. Interesting results were reported by Clark and Aramouni [16], who used breadfruit (*Artocarpus altilis*) as a wheat flour replacement. Maize [9], vegetables [54], bee pollen [17], dietary fibers [32], and acorn flour [8] are also other functional ingredients that have been used in gluten-free bread formulations in order to increase their

* Corresponding author at: Department of Chemical and Biological Engineering, Laboratory of Protein Engineering and Bioactive molecules (LR11ES24), INSAT-University of Carthage, Tunis, Tunisia.
E-mail addresses: Khemirisheyma@gmail.com (S. Khemiri), khelifi.nad@gmail.com (N. Khelifi), crnunes@gmail.com (M.C. Nunes), alice.ferreira@lneg.pt (A. Ferreira), Luisa.gouveia@lneg.pt (L. Gouveia), Issam.smaali@insat.rnu.tn (I. Smaali), anabraymundo@isa.ulisboa.pt (A. Raymundo).

https://doi.org/10.1016/j.algal.2020.101998
Received 16 February 2020; Received in revised form 1 July 2020; Accepted 2 July 2020