JOURNAL OF FUNCTIONAL FOODS 11 (2014) 375–392

Available at www.sciencedirect.com

ScienceDirect

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

Nutraceutical properties of phycocyanin

Berenice Fernández-Rojas [a], *Jesús Hernández-Juárez* [b], *José Pedraza-Chaverri* [a,*]

[a] *Departmento de Biología, Facultad de Química, UNAM, Ciudad Universitaria, México, D.F., 04510, México*
[b] *Unidad de Investigación Médica en Trombosis, Hemostasia y Aterogénesis del Hospital General Regional, No. 1 Dr. Dr. Carlos Mac Gregor Sánchez Navarro, IMSS, México, D.F., México*

ARTICLE INFO

Article history:
Received 5 September 2014
Received in revised form 6 October 2014
Accepted 7 October 2014
Available online

Keywords:
Phycocyanin
Functional food
Scavenging activity
Phycobyliprotein
Nutraceutical

ABSTRACT

Phycocyanin (PC) is one of the main pigments of the algae Spirulina, which is used as a dietary supplement due to its high protein content. PC is a protein from the phycobiliprotein family characterized by its intense blue color and its structure consists of a protein and non-protein components known as phycocyanobilin. PC scavenges reactive oxygen and nitrogen species (ROS and RNS, respectively) and prevents oxidative damage that may explain, at least in part, its beneficial effects. This review focuses on the beneficial characteristics and properties of PC emphasizing the antioxidant activity on *in vitro* and *in vivo* models. The use of PC in clinical trials is warranted.

Contents

* *Corresponding author.* Departmento de Biología, Facultad de Química, UNAM, Ciudad Universitaria, México, D.F., 04510, México. Tel.: +52 55 5622-3878; fax: +52 55 5622-3878.
E-mail address: pedraza@unam.mx (J. Pedraza-Chaverri).
http://dx.doi.org/10.1016/j.jff.2014.10.011
1756-4646/

1. Introduction

Recently, many scientific papers have focused their attention on health promoting properties of several foods (Avila-Nava et al., 2014; Braithwaite et al., 2014; Tahergorabi, Matak, & Jaczynski, 2014). The role of functional foods and their components in disease risk reduction, treatment and promotion of human health has been demonstrated (Griffiths, Abernethy, Schuber, & Williams, 2009; Lobo, Patil, Phatak, & Chandra, 2010; Tenore, Novellino, & Basile, 2012; Vulíc et al., 2014; Zhuang, Tang, & Yuan, 2013). Functional foods contain one or more bioactive(s) and as such nutraceutical are defined as compounds or products that have been isolated or purified from food sources that possess demonstrated health-promoting properties (Custódio et al., 2009; Lattanzio, Kroon, Linsalata, & Cardinali, 2009; Roberfroid, 2000). In this regard, phycocyanin (PC) is a nutraceutical compound with biological activity isolated and/or purified from seaweeds (De Jesus Raposo, de Morais, & de Morais, 2013; Pangestuti & Kim, 2011). PC has shown anti-inflammatory, antiplatelet, anti-cancer, nephroprotective and hepatoprotective properties that may be explained, at least in part, by its antioxidant activity. The aim of this review is to critically analyze the properties of PC and the results obtained from studies that show the involvement of the antioxidant activity of this protein in its nutraceutical properties.

2. General characteristics

PC is a protein from the phycobiliprotein (PBP) family (Patel, Mishra, Pawar, & Ghosh, 2005) characterized by its intense blue color. It is a peripheral accessory light-harvesting complex called phycobilisome (PBS), which is assembled on the surface of the thylakoid membrane. Its main function is to transfer the excitation energy to the center reaction where the maximum wavelength of absorption is near to 620 nm (Benedetti et al., 2006; De Marsac & Cohen-Bazire, 1977).

PC is one of the main pigments of Mexican algae Spirulina, which is used as a dietary supplement due to its high content of protein, vitamins, minerals and essential fatty acids (Ahsan, Mashuda, Tim, & Mohammad, 2008; Cherng, Cheng, Tarn, & Chou, 2007; Manconia et al., 2009; Thanh-Sang, BoMi, & Se-Kwon, 2013). This pigment is found in cyanobacteria and eukaryotic algae such as Rhodophyta and Cryptomonads (Glazer & Stryer, 1983). PC is classified into three types, C-PC (obtained from cyanobacteria), R-PC (obtained from red algae) and R-PCII (obtained from *Synechococcus* species) (Kuddus, Singh, Thomas, & Al-Hazimi, 2013; Wang et al., 2014). In this review, the general properties of the three types of PC are described. PC has been extracted from different algae sources (Table 1). In the Spirulina algae, PC provides its characteristic green–blue color (Eriksen, 2008; Gantar, Simović, Djilas, Gonzalez, & Miksovska, 2012; Silveira, Quines, Burkert, & Kalil, 2008).

Furthermore, PBPs are the most abundant proteins in many cyanobacteria and algae. However, it has been postulated that PBPs are not essential for the cell function because they are degraded when nitrogen is deprived. Therefore, PBPs are considered as a source of nitrogen storage (Sloth, Wiebe, & Eriksen, 2006).

PBPs are water soluble; they have bright color and are highly fluorescent. Also, they exhibit different and unique qualitative and quantitative features including a broad spectrum of visible light absorption and high absorption coefficient (Chattopadhyay et al., 2012; Glazer & Stryer, 1983).

PC purity is evaluated based on the absorbance ratio A620/A280. The absorbance at 620 and 280 nm correspond to PC and total protein, respectively (Patil, Chethana, Sridevi, & Raghavarao, 2006). PC is considered food grade when A620/A280 is ≤0.7, reagent grade when A620/A280 is between 0.7 and 3.9 and analytical grade when A620/A280 is ≥4.0 (Antelo, Anschau, Costa, & Kalil, 2010; Kuddus et al., 2013; Patil et al., 2006).

Equation (1) is used to determine the PC concentration (mg/mL) in crude extracts (Antelo et al., 2010; Bennett & Bogorad, 1973; Patel et al., 2005; Silveira et al., 2008).

$$[PC] = \frac{O.D._{\cdot 620nm} - 0.474\,(O.D._{\cdot 652nm})}{5.34} \quad (1)$$

The optical density at 652 nm corresponds to allophycocyanin; another PBP. The lethal dose 50 (LD_{50}) of PC analytic grade has not been established yet. The higher dose used with no observed adverse effect level (NOAEL) was studied by Romay, Ledón, and González (1998b); they found a NOAEL of 3 g/kg. Currently it has been shown that NOAEL of PC given orally is 5 g/kg (Ou, Lin, Pan, Yang, & Cheng, 2012). The NOAEL of