Food Chemistry xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Food Chemistry

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

Designing antioxidant peptides based on the antioxidant properties of the amino acid side-chains

Riko Matsui, Risa Honda, Mutsumi Kanome, Akari Hagiwara, Yuka Matsuda, Tomoka Togitani, Narumi Ikemoto, Masaaki Terashima*

Department of Biosphere Sciences, Kobe College, 4-1 Okadayama, Nishinomiya, Hyogo 662-8505, Japan

ARTICLE INFO

Keywords:
Amino acid
Antioxidant
Hypochlorite ion
Peptide
Peroxyl radical
Peroxynitrite

ABSTRACT

Amino acids exert characteristic antioxidant activities depending on the properties of their side residues. The hydrophobic residues were effective against peroxyl radical, while acidic residues and their analogs were effective against peroxynitrite. Peptides containing tyrosine showed different activities against different reactive oxygen species (ROS) and/or reactive nitrogen species (RNS). The number and position of tyrosine did not affect the antioxidant activity against hypochlorite ion. Against the peroxyl radical, the number of tyrosine residues affected the antioxidant activity, while its position did not have a significant effect. The tyrosine position was an important factor for the antioxidant activity against peroxynitrite. The peptide GWWW showed higher antioxidant activity against peroxyl radical than tryptophan at concentrations below 25 μM, and high activity against peroxynitrite at 250 μM. Our results suggest that antioxidant peptides against a specific target ROS or RNS can be designed based on the characteristics of the amino acid side chains.

1. Introduction

A variety of antioxidant peptides have been isolated from hydrolysates of foods, meat muscles, food byproducts and also from various plant proteins (Agrawal, Joshi, & Gupta, 2016; Chai, Law, Wong, & Kim, 2017; Wu et al., 2017; Sudhakar & Nazeer, 2017; Wang et al., 2017; Ramezanzade, Hosseini, & Nikkhah, 2017). The peptide YASGR isolated from a hydrolysate of dark chicken meat showed strong antioxidant activities against peroxyl radical, and the amino acid sequence of this peptide matched with the amino acid residues 143–147 of chicken β-actin (Fukada et al., 2016). Functional roles of some antioxidant peptides were demonstrated both in cultured cells and in vivo (Sheih, Fang, Wu, & Lin, 2010; Himaya, Ryu, Ngo, & Kim, 2012; Ko, Lee, Samarakoon, Kim, & Jeon, 2013). For example, AREGETVVPG, a peptide isolated from whole wheat products, was suggested to exert a protective role against high glucose-induced oxidative stress in vascular smooth muscle cells (Chen, Lin, Gao, Cao, & Shen, 2017). Additionally, egg white digested with trypsin showed an increasing effect in plasma radical scavenging in spontaneous hypertensive rats (Manso et al., 2008).

Various reactive oxygen species (ROS) and reactive nitrogen species (RNS) are generated by the metabolism of oxygen in vivo (Villamena, 2013). Super oxide anion, hydrogen peroxide, hydroxyl radical, peroxyl radical, and hypochlorite ion are typical ROS, and peroxynitrite is a representative RNS. The antioxidant activities of the amino acid side chain most likely determines the antioxidant activities of peptides because the thiol in cysteine, thioether in methionine, indole group in tryptophan, phenolic hydroxyl group in tyrosine, and imidazole group in histidine are relatively easily oxidized (Hougland, Darling, & Flynn, 2013). The amino acid sequence also has significant effects on the strength of the antioxidant activity of the peptides (Saito et al., 2003). Ohashi et al. (2015) examined the influence of the type and number of amino acid side chains on the antioxidant activities of tripeptides containing two tyrosines and tripeptides containing two histidines by six different antioxidant activity assays. The unique chemical and physical characteristics related to the amino acid sequence and structure of the peptide are important factors that determine their antioxidant activities (Elias, Kellerby, & Decker, 2008). Although amino acid residues should have different antioxidant activities against different ROS and RNS, the amount of comprehensive research on this subject is limited. One reason why the research is limited is because the conventional methods used to evaluate antioxidants are very time consuming. Our group proposed using a myoglobin method to evaluate the antioxidant activities of peptides against hypochlorite ion, hydroxyl radical, peroxyl radical, and peroxynitrite (Terashima, Nakatani, Harima, Nakamura, & Shiiba, 2007; Terashima, Watanabe, Ueki, & Matsumura, 2010). Unlike the ORAC method and the DPPH method, this method uses myoglobin, a biological component, as a probe. The

* Corresponding author.
E-mail address: terasima@mail.kobe-c.ac.jp (M. Terashima).

https://doi.org/10.1016/j.foodchem.2017.11.119
Received 17 September 2017; Received in revised form 30 November 2017; Accepted 30 November 2017

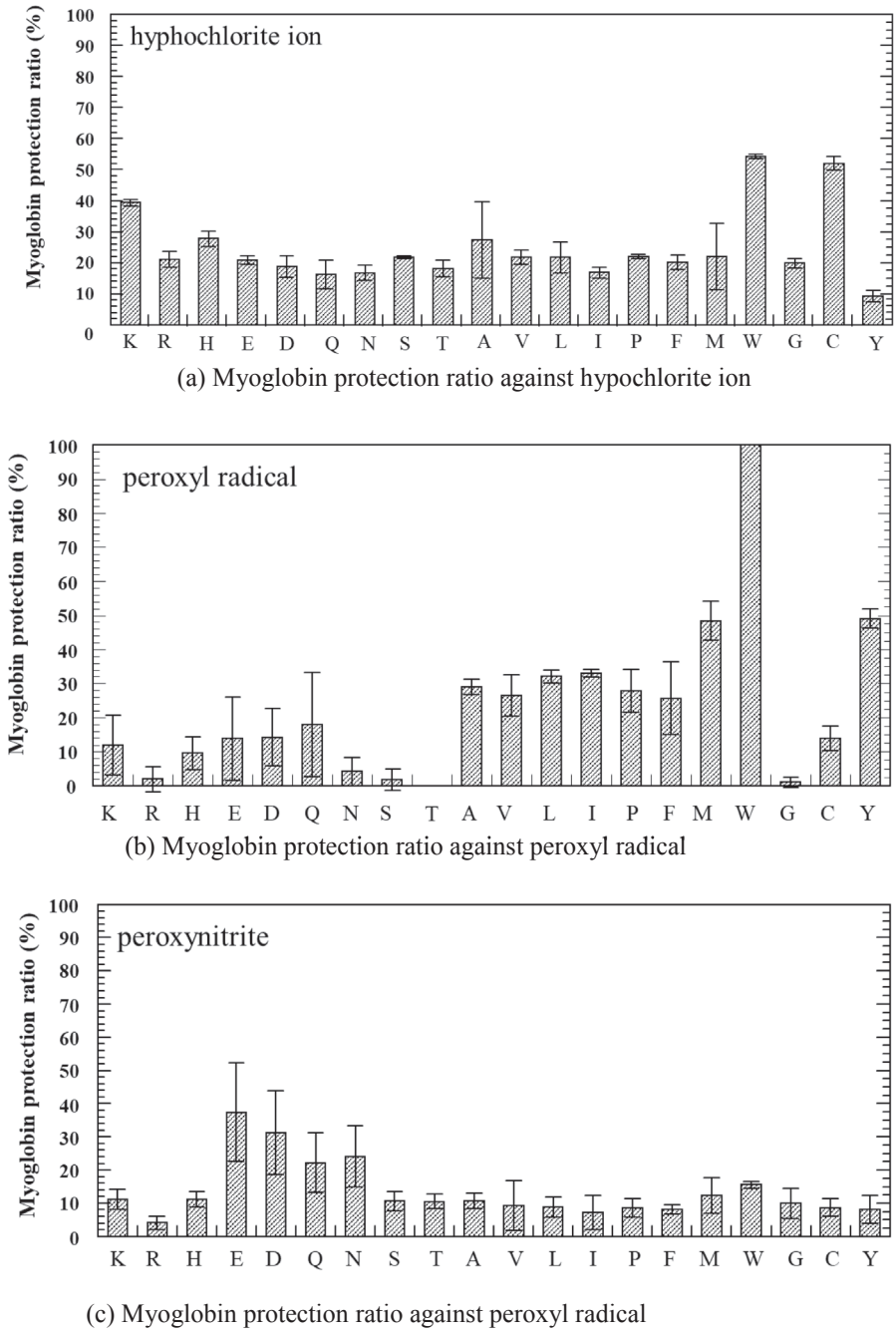

Fig. 1. Myoglobin protection ratios for amino acids against hypochlorite ion (a), peroxyl radical (b), and peroxynitrite (c).

antioxidant property of a substance is evaluated by its ability to suppress the structural change of myoglobin brought about by its reaction with ROS or RNS in this method. Therefore, it can be said that this method more reflects the reactivity of ROS or RNS with biological components than other methods. This protocol was applied to evaluate the antioxidant activities of flavonoids (Terashima et al., 2012), vegetables and beans (Terashima et al., 2013), and Japanese traditional seasoning miso (Morikawa et al., 2014). Since this protocol is simple and quick, it is suitable to analyze many samples in a short time, and successfully applied to screen antioxidant peptides against hypochlorite ion, hydroxyl radical, peroxyl radical, and peroxynitrite (Fukada et al., 2016).

In this work, the antioxidant activities of 20 amino acids against hypochlorite ion, hydroxyl radical, peroxyl radical, and peroxynitrite were evaluated using the myoglobin method. Four peptides, YGY, YGGY, GYYG, and GWWW, were designed based on the determined antioxidant properties of the amino acids. The numbers and position of the amino acid residues on the antioxidant activities of these peptides were studied.

2. Materials and methods

2.1. Materials

Myoglobin (equine skeletal muscle, 95–100%) and peroxynitrite were purchased from Sigma-Aldrich (USA) and Dojin Chemicals (Japan), respectively. The synthetic peptides GYG, GYYG, YGGY, and GWWW (purity > 98.0%), were purchased from Funakoshi Corporation (Japan). All other reagents were of reagent grade.