Food Chemistry 125 (2011) 1226–1234

Contents lists available at ScienceDirect

Food Chemistry

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

Ecdysteroids from *Chenopodium quinoa* Willd., an ancient Andean crop of high nutritional value

Saowanee Kumpun [a,b,1], Annick Maria [a], Sophie Crouzet [c], Nathalie Evrard-Todeschi [d], Jean-Pierre Girault [d], René Lafont [a,c,*]

[a] UPMC-Université Paris 6, Laboratoire BIOSIPE – ER3, Case Courrier 29, 7 Quai St. Bernard, 75252 Paris 05, France
[b] Department of Chemistry, Faculty of Science, Ramkhamhaeng University, Bangkok 10240, Thailand
[c] Institut Biophytis, Parc BIOCITECH, Route de Noisy, 102 Avenue Gaston Roussel, 93230 Romainville, France
[d] Université René Descartes, Laboratoire de Chimie et Biochimie Pharmacologiques et Toxicologiques, CNRS UMR 8601, 45 rue des Saints-Pères, 75270 Paris Cedex 06, France

ARTICLE INFO

Article history:
Received 6 March 2010
Received in revised form 25 July 2010
Accepted 7 October 2010

Keywords:
Pseudocereals
Chenopodium quinoa
Phytoecdysteroid
20-Hydroxyecdysone

ABSTRACT

Chenopodium quinoa Willd. (=quinoa) is a crop cultivated since ancient times by the Incas, which has a high nutritional value. Quinoa belongs to Chenopodiaceae, a family containing many ecdysteroid-containing species, including spinach.

Quinoa seeds have been investigated for their ecdysteroid content. Besides large amounts of 20-hydroxyecdysone, they contain lower amounts of makisterone A, 24-*epi*-makisterone A, 24(28)-dehydromakisterone A and polypodine B, together with a wide array of minor ecdysteroids, among which three were isolated as new natural compounds, i.e. 24,25-dehydroinokosterone, 25,27-dehydroinokosterone and 5β-hydroxy-24(28)-dehydromakisterone A. Ecdysteroids are concentrated in the bran, and their amount varies with the quinoa variety used. Most of the 20-hydroxyecdysone is recovered undegraded within the seeds even after 20 min boiling, and is thus susceptible to evoke significant (beneficial) pharmacological effects on humans who eat quinoa regularly. The same applies to most quinoa-based foods, which retain most of their original ecdysteroid content.

1. Introduction

Ecdysteroids are both insect moulting hormones (zooecdysteroids) and plant secondary metabolites (phytoecdysteroids) which protect plants against non-adapted insects and nematodes (Dinan, Harmatha, Volodin, & Lafont, 2009). Ecdysteroids evoke various pharmacological effects on mammals and humans (Báthori & Pongrácz, 2005; Dinan & Lafont, 2006, 2009; Lafont & Dinan, 2003). Most of the reported effects are rather beneficial to human health, e.g. reduction of glycaemia of diabetic patients, reduction of cholesterolaemia, and possibly also prevention of osteoporosis (Gao, Cai, & Shi, 2008; Seidlova-Wuttke, Ehrhardt, & Wuttke, 2010). Ecdysteroids also have anabolic effects (Tóth, Szabó, Kacsala, Héger, & Zádor, 2008) connected with a general stimulation of protein synthesis (Okui et al., 1968) and an increasing number of ecdysteroid-containing preparations are proposed for sportsmen and bodybuilders (Báthori, Tóth, Hunyadi, Márki, & Zádor, 2008; Lafont & Dinan, 2003).

Although present in many wild plant species (Dinan, 2001), phytoecdysteroids are essentially absent from cultivated ones, maybe because these have been selected to give higher yields and their production of secondary metabolites was therefore possibly counter-selected. Significant presence of phytoecdysteroids in human food seems limited to a few plant species, including spinach and a few other Chenopodiaceae (Dinan, Whiting, & Scott, 1998), yam (Sautour, Canon, Miyamoto, Dongmo, & Lacaille-Dubois, 2008) and, to a lower extent, button mushrooms (Findeisen, 2004). *Chenopodium quinoa* Willd. (=quinoa) is a crop cultivated from ancient times by the Incas and is mainly produced in Bolivia. Quinoa culture has recently been introduced on a small scale in other countries (South America, USA, Denmark, etc.); the interest of this crop being that it accommodates rather poor soils and water shortage. On the other hand, the yield (0.4 to at best 2 ton/ha) is low when compared with wheat or maize. Quinoa seeds represent an interesting foodstuff, owing to their high protein content (with all essential aminoacids) and lack of gluten (Dini, Tenore, & Dini, 2002, 2005).

The presence of ecdysteroids in *Chenopodium quinoa* was first documented in whole plants by Báthori et al. (1984). Preliminary

* Corresponding author at: UPMC-Université Paris 6, Laboratoire BIOSIPE – ER3, Case Courrier 29, 7 Quai St. Bernard, 75252 Paris 05, France. Tel.: +33 1 44272263; fax: +33 1 44272361.
E-mail address: rene.lafont@snv.jussieu.fr.fr (R. Lafont).
[1] Present address: Department of Chemistry, Faculty of Science and Technology, Suan Sunandha Rajabhat University, Bangkok 10300, Thailand.

0308-8146/$ - see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.foodchem.2010.10.039

studies on quinoa seeds showed the presence of significant amounts (ranging from 450 to 1300 μg/g ecdysone equivalents) of ecdysteroids (Dinan et al., 1998). A first phytochemical analysis of whole seeds (Zhu et al., 2001) identified its main ecdysteroids, i.e. a major one, 20-hydroxyecdysone (30 μg/g) and several minors (3–9 μg/g), i.e. makisterone A, 24-*epi*-makisterone A, 24(28)-dehydro-makisterone A, and 20,26-dihydroxyecdysone (see Fig. 1 for formulae). Later, Dini et al. (2005) showed that quinoa flour contains both 20-hydroxyecdysone and a unique ecdysteroid, kancollosterone. More recently, a new set of ecdysteroids was isolated from quinoa seeds, including again two original ecdysteroids (Nsimba, Kikuzaki, & Konishi, 2008).

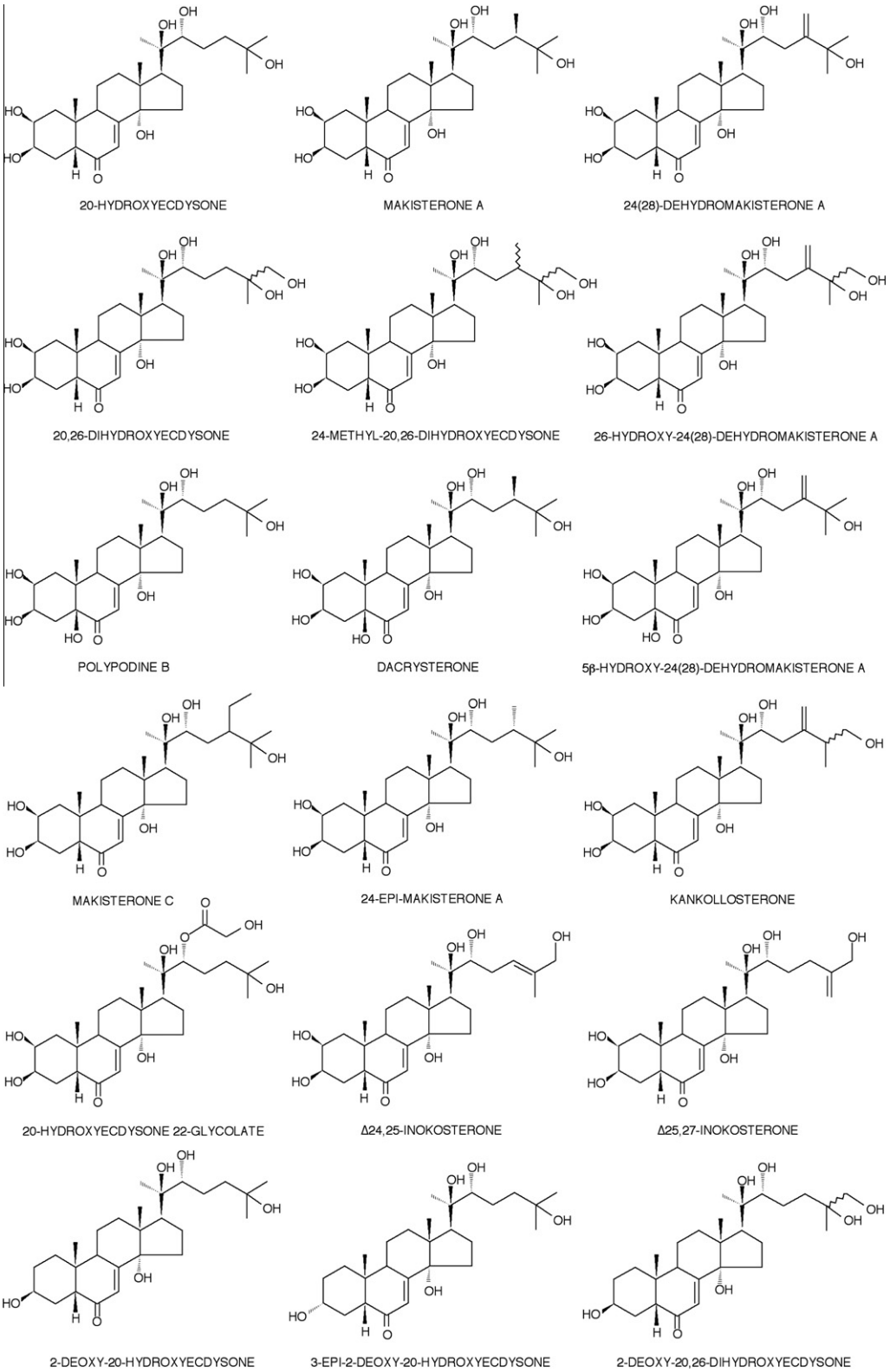

Fig. 1. Structural formulas of quinoa ecdysteroids.