Forensic Science International 198 (2010) 46–52

Contents lists available at ScienceDirect

Forensic Science International

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

Potential of IRMS technology for tracing gamma-butyrolactone (GBL)

François Marclay [a,1], Diego Pazos [b,1], Olivier Delémont [b], Pierre Esseiva [b,*], Christophe Saudan [a]

[a] Swiss Laboratory for Doping Analyses, University Centre of Legal Medecine, Geneva and Lausanne, Centre Hospitalier Universitaire Vaudois and University of Lausanne, Ch. des Croisettes 22, 1066 Epalinges, Switzerland

[b] Institut de Police Scientifique, Ecole des Sciences Criminelles, Université de Lausanne, Batochime, 1015 Lausanne-Dorigny, Switzerland

ARTICLE INFO

Article history:
Received 19 August 2009
Received in revised form 3 December 2009
Accepted 8 December 2009
Available online 6 January 2010

Keywords:
Drug of abuse
Isotope ratio mass spectrometry
Gamma hydroxy butyric acid
Gamma butyrolactone

ABSTRACT

Popularity of γ-hydroxybutyric acid (GHB) is fairly stable among drug users, while the consumption of its chemical precursor, γ-butyrolactone (GBL), is a growing phenomenon. Although conventional analytical methods allow to detect this substance in various matrices, linking a trace and a source is still a difficult challenge. However, as several synthesis pathways and chemical precursors exist for the production of GBL, its carbon isotopic signature may vary extensively. For that purpose, a method has been developed to determine the carbon isotopes content of GBL by means of gas chromatography/combustion/isotope ratio mass spectrometry (GC/C/IRMS).

The δ^{13}C-values of 19 bulk samples purchased worldwide were in the range from -23.1 to -45.8‰ (SD < 0.3‰). Furthermore, testing on the purification of GBL by distillation has not been found to be consistent with such a large range of δ^{13}C-values, which are likely to result from the isotopic composition of the organic precursors used to produce GBL together with the kinetic isotope effect associated with the synthesis routes. Finally, inter- and intra-variability measurements of the δ^{13}C-values demonstrated the high potential of IRMS for discriminating between seizures of GBL and for source determination.

1. Introduction

The demand for γ-butyrolactone (GBL) has increased in the last decade, mainly as a chemical intermediate to manufacture polymers, but also as a biodegradable degreaser or paint remover [1]. In 2002, the domestic production in the USA was estimated at 80,000 tons per year [2]. The total capacity of GBL manufacturing in China was reported in 2006 to be around 50,000 tons per year [3]. As illustrated in Fig. 1, several chemical intermediates may be potentially converted into GBL at the industrial level. The major portion of GBL is currently being produced via the dehydrogenation of 1,4-butanediol (1,4-BD) [4–6], which is manufactured from the reaction of acetylene with formaldehyde; this reaction is known as the Reppe process [7]. New manufacturing routes of GBL are based on the two-stage hydrogenation of economically attractive raw materials such as dimethyl maleate [8] or maleic anhydride [9–11]. Tetrahydrofurane can also be used as a precursor to synthesize GBL following a single oxidation step [12].

Recreative use of γ-hydroxybutyric acid (GHB) and to a lesser extent GHB-facilitated sexual assaults ('date rape') is a relatively recent and stable phenomenon among European countries [13,14]. However, recent surveys indicate that consumption of its chemical precursors, namely GBL and 1,4-BD, is a growing trend among drug users due to several promoting factors [15]. Starting with these materials, the synthesis of GHB is rather simple and, most remarkably, these precursors exhibit a rapid conversion into GHB by peripheral lactonase upon direct oral consumption [2,16–18]. Moreover, both GBL and 1,4-BD would hardly be regulated under a national or an international legislation as they are important and common industrial solvents used in large quantities in the synthesis of plastics and polymers [13,19]. The lack of control coupled with the availability of these substances on the internet for a relatively cheap price increase the popularity of GHB, GBL and 1,4-BD consumption. Therefore, there is a need to develop analytical means to assist law enforcement agencies disrupt the use and trafficking of GHB and its precursors.

In forensic cases, the presence of GHB or precursors is investigated in items seized at the premises, in the form of drug samples or spiked beverages, but also as biological samples (urine or blood) collected from drug users or sexual assault victims. Although these substances may be detected by conventional analytical methods, any linkage between trace and source is difficult to ascertain. However, as these substances can be synthesized through many different routes using a diversity of chemicals, variations in their stable isotopes content may be potentially observed. In that respect, several investigations of

---

[*] Corresponding author at: Institut de Police Scientifique, 1015 Lausanne-Dorigny, Switzerland. Tel.: +41 216924652; fax: +41 216924605.
E-mail address: Pierre.esseiva@unil.ch (P. Esseiva).

[1] These authors contributed equally to this work.

0379-0738/$ – see front matter © 2009 Elsevier Ireland Ltd. All rights reserved.
doi:10.1016/j.forsciint.2009.12.014

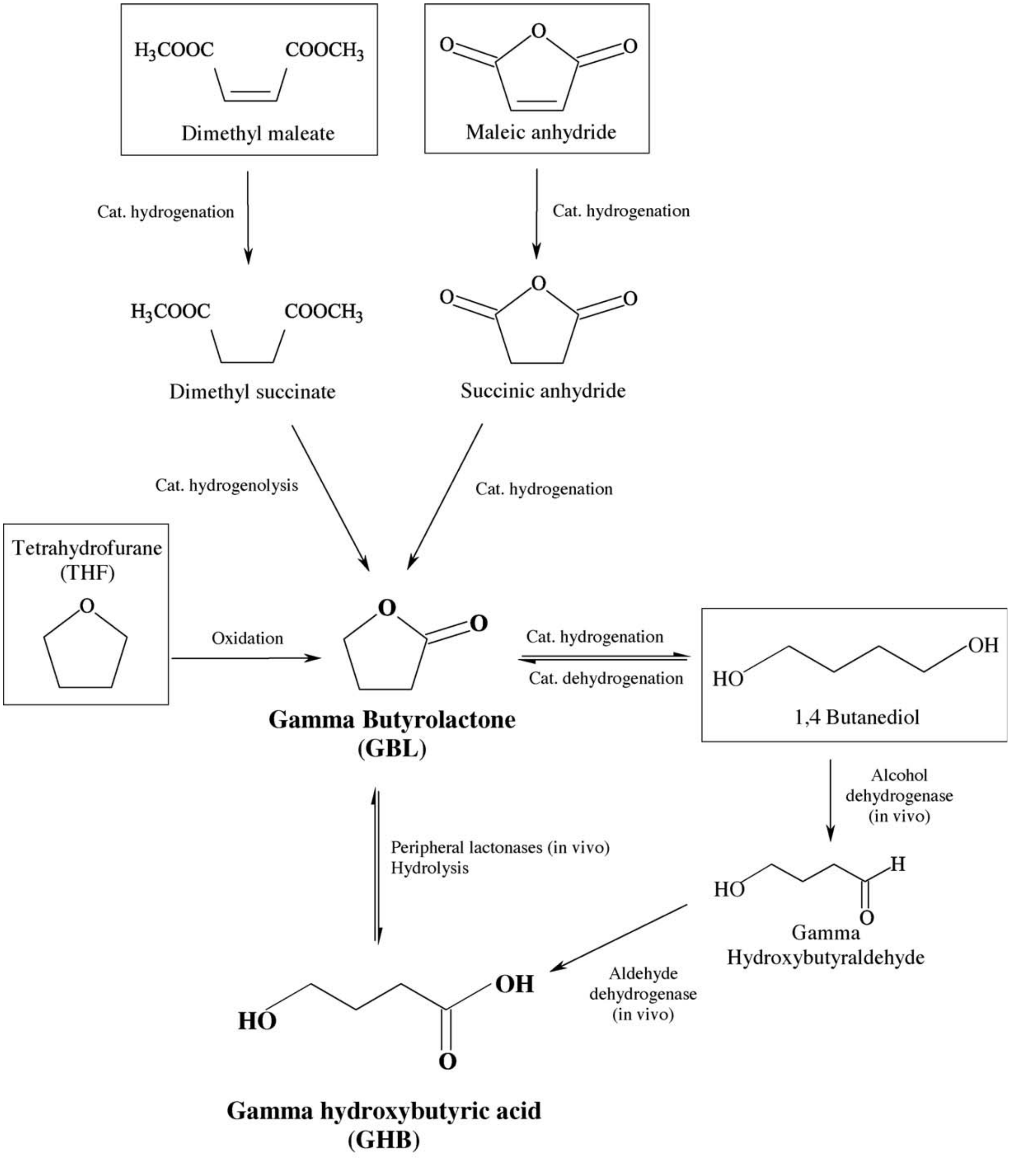

Fig. 1. Structures and synthesis pathways of synthetic precursors of γ-butyrolactone.

stable isotopes have been conducted to assist in determining the manufacturing source of illicit synthetic drugs such as amphetamine type stimulants based molecules [20].

In the present study, an appropriate and robust gas chromatography/combustion/isotope ratio mass spectrometry (GC/C/IRMS) method has been developed and tested for the characterization of GBL samples. Then, the variability in the carbon isotopic compositions between samples of GBL purchased from different chemical providers and internet retailers of various countries in the world has been studied. The distillation effect has also been evaluated as it takes place in the production of GBL and thus may possibly affect the isotope ratio value. Finally, the discriminating ability of IRMS to infer the source of GBL samples will be discussed. This work provides a baseline for future studies and some explanation to understand the variations in the carbon isotope composition of GBL.

2. Materials and methods

2.1. Chemicals

Dichloromethane (≥99.9%) was purchased from Merck (Darmstadt, Germany). γ-Butyrolactone (GBL) was purchased from Fluka (≥99.0%, Lot 001363070, Buchs, Switzerland), Sigma (≥99.0%, Lot 087K3521, Buchs, Switzerland), Lipomed (>99.0%, Lot 823.1B0.1L5, Arlesheim, Switzerland) and Wako (>99.0%, Lot PEN6670, Osaka, Japan). ε-Caprolactone (≥99.0%, Lot 1256826) was obtained from Fluka (Buchs, Switzerland). Helium (Quality 60, >99.9999%) and carbon dioxide gas (Quality 40, >99.99%) were purchased from Carbagas (Domdidier, Switzerland). Tetradecanoic acid methyl ester (C14:0, #14M, $C_{15}H_{30}O_2$, $\delta^{13}C = -29.98 \pm 0.02‰$, >99.0%) was obtained from Arndt Schimmelmann (Indiana University, Department of Geological Sciences, Biogeochemical Laboratories, 1001 East 10th Street, Bloomington, IN, USA).