Food Chemistry 166 (2015) 486–491

Contents lists available at ScienceDirect

Food Chemistry

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

Content and evolution of potential furfural compounds in commercial milk-based infant formula powder after opening the packet

Jorge L. Chávez-Servín [a,*], Karina de la Torre Carbot [a], Teresa García-Gasca [a], Ana I. Castellote [b,c], M. Carmen López-Sabater [b,c]

[a] Facultad de Ciencias Naturales, Campus Juriquilla, Universidad Autónoma de Querétaro, Av. de las Ciencias S/N, Juriquilla, Querétaro, Qro. CP 76320, Mexico
[b] Department of Nutrition and Food Science, Faculty of Pharmacy, University of Barcelona, Av. Joan XXIII s/n, E-08028 Barcelona, Spain
[c] CIBER Physiopathology of Obesity and Nutrition (CIBEROBN), Institute of Health Carlos III, Spain

ARTICLE INFO

Article history:
Received 23 January 2014
Received in revised form 6 May 2014
Accepted 9 June 2014
Available online 18 June 2014

Keywords:
Furfural compounds
Milk-based formula powders
Maillard reaction
Stability

ABSTRACT

Potential furfural compounds were examined by RP-HPLC-DAD in 20 commercial milk-based powdered infant formula (IF) brands from local markets from Paris, France; DF, Mexico; Copenhagen, Denmark; England, UK; and Barcelona, Spain. We traced the evolution of these compounds after the packets had been opened at 0, 30 and 70 days of storage at room temperature (≈25 °C; minimum 23 °C and maximum 25.5 °C). All formula brands were analysed during the first 3–5 months of their shelf life. The mean values of all IFs for potential 5-hydroxymethyl-2-furaldehyde (HMF) + 2-furaldehyde (F) were 1115.2 μg/100 g (just opened), 1157.6 μg/100 g (30 days) and 1344.5 μg/100 g of product (70 days). In general, slight increases of potential furfural contents were observed in most of the studied IFs, which suggests that the Maillard reaction increases after opening the packets. The main furfural compound found was HMF, as expected. The range of potential HMF consumed for an infant about 6 months old feeding only on formula was estimated between 0.63 mg and 3.25 mg per day.

1. Introduction

The food industry has strived to improve the quality and the nutritional composition of infant formula (IF), in an effort to make them similar to human milk. This is particularly important in instances when breastfeeding is not an option (Ferreira, Gomes, & Ferreira, 1998). Most IF brands on the market are in the form of a powder, made mainly from bovine milk. Conventional bovine milk-based formula is generally manufactured using specific combinations of protein, fat, carbohydrates, vitamins, minerals and other minor components. In the standard production of IF, the raw material mix is blended, pasteurised, homogenised, condensed and spray-dried or sterilised. The redistribution and interactions of the components in the system occur during processing and storage (Chávez-Servín, Castellote, & Lopez-Sabater, 2008b; Guo, Hendricks, & Kindstedt, 1998). The stability of these IFs brands must be monitored. Instability can result from various factors, including lower sugar content, the use of lysine-rich proteins, the application of high temperature during production, pH, water activity, the concentration of divalent cations of the media and long storage periods. pH can promote the formation of furfural compounds, either by lactose isomerisation (Lobry De Bruyn–Alberda van Ekenstein transformation, L–A) or by Amadori compound formation (Ferrer, Alegria, Farre, Abellan, & Romero, 2002). In an acidic medium, the dehydration of carbohydrates leads to the formation of HMF. Moreover, MR can also take place, producing Amadori compounds during the first steps of this reaction, and HMF as a consequence of further reactions (Rada-Mendoza, Sanz, Olano, & Villamiel, 2004). On the other hand, basic media could cause the formation of Amadori compounds, and consequently, the formation of furfurals. This makes the formula susceptible to the Maillard reaction (MR), which affects the stability and nutritional composition of the formula (Agostoni et al., 1999; Baltes, 1982; Chávez-Servín, Castellote, & Lopez-Sabater, 2008a; Guo et al., 1998; Vanmil & Jans, 1991).

Furfurals, undesirable compounds derived from the MR, are formed during the thermal process and/or during storage. The main furfurals reported are 5-hydroxymethyl-2-furaldehyde (HMF), 2-furaldehyde (F) 2-furyl-methyl ketone (FMC) and 5-methyl-2-furaldehyde (MF). Their presence is a useful indicator of food damage and the extent of MR in the IF (Guerra-Hernandez, Garcia-Villanova, & Montilla-Gomez, 1992; Lococo,

* Corresponding author. Tel.: +52 442 192 12 00x5308.
E-mail address: jorge.chavez@uaq.mx (J.L. Chávez-Servín).

http://dx.doi.org/10.1016/j.foodchem.2014.06.050
0308-8146/

Valentini, Novelli, & Ceccon, 1994; Oral, Mortas, Dogan, Sarioglu, & Yazici, 2014; Pereyra Gonzales, Naranjo, Malec, & Vigo, 2003).

Furfurals are both the result of Amadori compounds from the MR or of lactose isomerisation, also known as the Lobry De Bruyn–Alberda van Ekenstein transformation (L–A), and the subsequent degradation reactions (Chávez-Servín, Castellote, & López-Sabater, 2005; Morales & Jimenez-Perez, 1998; van Boekel, 1998). HMF is considered as the main quality index in several food products. Its concentration is adversely associated with the healthiness of the product, since high concentrations of HMF have been reported to have cytotoxic effects on the upper respiratory tract, skin and mucous membranes (Capuano & Fogliano, 2011), and other adverse effects in rodents as carcinogenic activity and related harmful effects (Anese & Suman, 2013; Toker, Dogan, Ersöz, & Yilmaz, 2013).

There are some studies of furfural content in IFs and milk-powder products during storage time (Albalá-Hurtado, Veciana-Nogues, Izquierdo-Pulido, & Vidal-Carou, 1997; Chávez-Servín, Castellote, & López-Sabater, 2006; Chávez-Servín et al., 2005; Ferrer, Alegria, Farre, Abellan, & Romero, 2000, 2005). IF brands are usually packaged in a controlled atmosphere and are protected from light and maintained at room temperature. When the packet is opened, IF is highly susceptible to lipid oxidation, and light accelerates this process (Hardas, Danviriyakul, Foley, Nawar, & Chinachoti, 2000). This could affect the MR process. There is a lack of information on furfural concentration and evolution in commercial IF once the packet is opened. According to the manufacturers' instructions, once the packet is opened, IF should be used within one month. Generally, IF is consumed before this time. Although any remaining formula should be discarded 30 days after opening the package, according to the manufacturers' recommendations, consumers may inadvertently store it for longer (i.e. When IF are used for complementary feeds. Therefore, it is also of particular interest to know what happens with the content of potential furfurals after the formula's expiration date. For these reasons, it would be of interest to study the content and evolution of furfurals not only during the one-month life of IF once the packet is opened, but also after this time, extending the analysis to 70 days, a period that more than doubles the established time for formula consumption.

The aim of the present study was to trace the content and evolution of potential furfural compounds (HMF, F, FMC and MF) in commercial IF brands for 70 days after opening the packet, using RP-HPLC-DAD monitoring.

2. Materials and methods

2.1. Samples

Twenty well-known commercial milk-based powdered IF brands were purchased in several markets from Paris, France; DF, Mexico; Copenhagen, Denmark; England, UK; and Barcelona, Spain. Table 1 indicates the general composition of the studied formula brands, as stated on the product label.

2.2. Storage

All IF packets were opened on the same day; approximately in the 3–5 month of their shelf lives. In addition, the IF packets were opened three times every day thereafter; each time the powder was stirred in the original packet to maintain uniform exposure

Table 1
Composition of infant milk-based formula as stated on product labels.

Formula[a]	C [b]	L[b]	P[b]	Main ingredients[c]
IF1 A Can 900g	58.7	24.0	12.0 (40/60)	Demineralised whey milk, palm oil, skim milk, maltodextrins, vegetal oils (colza, sunflower)
IF2 B Can 450g	58.6	24.0	12.5 (NA)	Demineralised whey milk, skim milk, palm olein, maltodextrin, colza, palm and corn oils, soybean lecithin
IF3 B Can 450g	58.6	24.0	12.5 (NA)	Demineralised whey milk, palm olein, starch, skim milk, corn syrup, colza, coconut and corn oils
IF4 C Bag 450g	58.6	24.4	11.7 (NA)	Demineralised whey milk, milk powder (partially demineralised), vegetable oils (palm, colza, sunflower), lactose
IF5 D Can 400g	56.0	28.0	11.6 (40/60)	Demineralised whey milk, vegetable oils, skimmed milk powder, lactose, soybean lecithin and monoglycerides of fatty acids
IF6 B Can 450g	55.6	24.0	12.5 (NA)	Demineralised whey milk, palm olein, starch, skim milk, corn syrup, colza, coconut and corn oils
IF7 A Can 400g	50.0	25.4	12.1 (50/50)	Demineralised whey milk, vegetable oils (palm, coconut, soybean), lecithin
IF8 A Can 900g	59.7	24.5	11.0 (60/40)	Skim milk, vegetal fat matters (palm, coconut, colza and sunflower), demineralised whey milk, maltose, maltodextrins, soybean lecithin
IF9 B Can 400g	58.3	23.1	12.8 (NA)	Skim milk, lactose, starch, palm olein, demineralised whey milk, colza, coconut and sunflower oils, soybean lecithin
IF10 E Can 900g	58.0	26.0	9.5 (NA)	Skim milk, vegetable oils (palm, coconut, sunflower, soybean, high oleic acid), LC-PUFA (arachidonic and docosahexaenoic acid), lactose, maltodextrin, milk proteins, soybean lecithin
IF11 B Can 400g	56.0	28.0	11.0 (40/60)	Skim milk, lactose, vegetal oils, fractionated milk protein (α-lactoalbumin), soybean lecithin, LC-PUFA (arachidonic and docosahexaenoic acid)
IF12 C Bag 500g	55.0	27.0	11.5 (NA)	Skim milk, fat milk, lactose, lactose, vegetable oils (palm, sunflower, colza) milk proteins
IF13 A Can 1000g	52.4	27.5	13.9 (70/30)	Skim milk, lactose, glucose syrup, vegetal oils (palm, colza, corn and coconut)
IF14 E Bag 400g	58.3	26.0	10.7 (40/60)	Lactose, vegetable oil, skim milk, maltodextrin, serum protein, egg phospholipids
IF15 B Can 450g	56.0	29.0	11.0 (NA)	Lactose, skim milk, palm oil, whey milk protein concentrate, coconut and soybean oils, vegetable oil rich in oleic acid, soybean lecithin
IF16 B Can 400g	56.0	29.0	11.0 (NA)	Lactose, skim milk, palm oil, whey milk protein concentrate, coconut and soybean oils, vegetable oil rich in oleic acid, soybean lecithin
IF17 B Can 400g	57.7	26.0	11.5 (NA)	Hydrolysed whey milk protein minerals reduced, corn syrup, vegetable oils (palm olein, canola, coconut, sunflower, high oleic acid)
IF18 B Can 400g	56.4	26.4	11.5 (NA)	Hydrolysed whey milk protein minerals reduced, vegetable oils (palm olein, soybean, coconut, sunflower, high oleic acid), lactose, corn maltodextrin
IF19 D Bag 459g	60.5	28.2	11.3 (NA)	Whey powder, vegetable oils, skimmed milk, lactose, galacto-oligosaccharides, polyfructose, fish oil
IF20 A Can 400g	60.0	23.9	11.2 (60/40)	Milk protein, skim milk, whey protein milk, vegetable oils (palm, coconut, colza, sunflower), lactose, carob flour, glucose syrup

Abbreviations: C = carbohydrates, L = lipids, P = protein: (casein/serum protein) is indicated if available, NA = not available.
[a] We indicated the sampling region in which they obtained (A: Paris, France; B: DF, Mexico; C: Copenhagen, Denmark; D: England, UK; E: Barcelona, Spain) and the formula presentation.
[b] Expressed as g/100 g of powder.
[c] Ingredients are listed in the order in which they appear on the label.