Journal of Food Engineering xxx (2012) xxx–xxx

Contents lists available at SciVerse ScienceDirect

Journal of Food Engineering

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

Cocoa butter fats and possibilities of substitution in food products concerning cocoa varieties, alternative sources, extraction methods, composition, and characteristics

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ARTICLE INFO

Article history:
Available online xxxx

Keywords:
Natural cocoa butter
Cocoa butter alternative
Fatty acid
Triglyceride
Cocoa butter properties

ABSTRACT

The current concern for cocoa butter fat as major ingredients of chocolate intake in the World has raised the question of the high price of cocoa butter among all other vegetable fats. Productions of natural cocoa butter fats are decreasing day by day due to the decrease of cocoa cultivation worldwide; moreover, cocoa fruit contains only a little amount of cocoa butter. Therefore, the food industries are keen to find the alternatives to cocoa butter fat and this issue has been contemplated among food manufacturers. This review offers an update of scientific research conducted in relation to the alternative fats of cocoa butter from natural sources. The findings highlights how these cocoa butter alternatives are being produced either by blending, modifying the natural oils or fats from palm oil, palm kernel oil, mango seed kernel fats, kokum butter fat, sal fat, shea butter, and illipé fat.

1. Introduction

Food industries are keen to find for alternative fats to cocoa butter (CB) from natural matrices that are denoted as cocoa butter replacers (CBRs), cocoa butter equivalents (CBEs), and cocoa butter substitutes (CBSs) fat. CB is a natural fat obtained from cocoa seeds (*Theobroma cacao*). It is commonly used as an essential major ingredient of chocolate and other confectionary products due to its specific physical and chemical properties. CB is solid at room temperature (below 25 °C) and at body temperature (~37 °C) it is liquid. CB mainly consists of palmitic acid (C_{16}), stearic acid ($C_{18:0}$), Oleic acid ($C_{18:1}$) and linoleic acid ($C_{18:2}$) but low amount of lauric acid (C_{12}) and myristic acid (C_{14}). CB can crystallize into several polymorphic forms, having α, γ, β′, and β crystals, with melting points of 17, 23, 26, and 35–37 °C respectively. In the chocolate production, only β crystal is used because it has a high melting point. This crystal structure confers chocolate products an excellent quality in terms of sheen, snap, and smooth texture. In addition, CB exhibits resistance to fat bloom, arising from changes in the fat in the chocolate during storage. This can be seen as undesirable white or streaky grey-white spots on the chocolate surface.

Cocoa butter (CB) is highly appreciated and is expensive compared with all other vegetable fats and oils because of its specific characteristics. Another important reason is that cocoa beans contain low amount of CB fat (Zaidul et al., 2007c). Moreover, cocoa has only been cultivated in a few countries (Hassan et al., 1995; Moreton, 1988). However, many researchers have produced cocoa butter alternative fats either by fractionation and blending or enzymatic interesterification of palm kernel oil (PKO) and palm oil (PO) (Bloomer et al., 1990; Calliauw et al., 2005; Hashimoto et al., 2001; Undurraga et al., 2001; Zaidul et al., 2007c), mango seed fat (Ali et al., 1985; Jiménez-Bermúdez et al., 1995; Kaphueakngam et al., 2009; Lakshminarayana et al., 1983; Solís-Fuentes, 1998), kokum butter (Maheshwari and Reddy, 2005; Reddy and Prabhakar, 1994), Sal fat (Gunstone, 2011; Reddy and Prabhakar, 1989), Shea butter (Olajide et al., 2000), and illipé fat (Gunstone, 2011). The cocoa butter alternatives or cocoa butter replacers (CBRs) are defined as non-lauric fats that could replace cocoa butter either partially or completely in the chocolate or other food products (Kheiri, 1982). The fatty acid compositions of CBRs are similar to that of CB with more or less similar triglycerides structure. It should be cheaper than that of CB. CBRs can be divided into two groups, namely cocoa butter equivalents (CBEs) and cocoa butter substitutes (CBSs). CBEs

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http://dx.doi.org/10.1016/j.jfoodeng.2012.09.024

are vegetable fats which have similar physical and chemical characteristics like CB. Therefore, CBEs can be mixed with CB in any amount without changing the behaviour of the final product. The major fatty acids contained in CBEs are palmitic acid, stearic acid and oleic acid, which are similar to that of CB. CBEs are divided into two subgroups, namely cocoa butter extenders (CBEXs) and cocoa butter improvers (CBIs) (Lipp and Anklam, 1998). CBEXs cannot be mixed with CB in every proportion, while CBIs are similar to CBEs, contain higher level of solid triglycerides, and because of this characteristic it is commonly used for improving soft cocoa butters. In this paper the CBEXs and CBIs all are referred to as CBEs. Cocoa butter substitutes (CBSs) are lauric and myristic plant fats (containing lauric and myristic acid) with some physical similarities to CB, but chemically they are completely different. Therefore, they are suitable for wholly replacement of CB. The aim of this review paper is to discuss the various vegetable fats used as proposed or alternatives to cocoa butter in chocolate and other confectionary products. The compatibility of some important properties of the resulting alternative cocoa butter fats such as triglycerides in terms of fatty acid constituents, slip or sharp melting points, solid fat contents, iodine value, acid value and saponification values will also be discussed.

2. Background of cocoa cultivation

The generic name of cocoa is *Theobroma* belonging to the family of Sterculiaceae, also called "Food of God". It contains about 30–50 beans, covered with pulp. About 500 years ago, cocoa beans were originated from Latin America, and within a few years it spread to Europe. From there it was then distributed throughout the World (International Cocoa and Commodities Organisation, ICCO, 2000). In Central America, cocoa was widely cultivated by the Mayas. Mayas and Aztecs were the first to consume cocoa. In the 16th century, the Spanish were the first Europeans to drink cocoa. Spanish people, namely Capuchin friars, successfully grew cocoa in Ecuador in about 1635. In the 17th century, the Europeans began cocoa cultivation widely. France introduced cocoa to St Lucia (1660), the Dominican Republic (1665), Brazil (1677), Guianas (1684), and Grenada (1714); England was growing cocoa in Jamaica by 1670. Later, cocoa was introduced in Africa. The cocoa from Brazil was cultivated in Principe in 1822, Sao Tomé in 1830, Fernando Po in 1854, then in Nigeria in 1874, and Ghana in 1879. From 1925 to 1939, cocoa was introduced in Cameroon. In 1560, the Dutch people first introduced Venezuelan Criollo type cocoa in Southeast Asia and Oceania, in particular, in Celebes and Java. The Criollo type of cocoa from Mexico was introduced into the Philippines by the Spanish in 1614. Cocoa was introduced into Sri Lanka from Trinidad in 1798, from where it spread to Singapore and Fiji in 1880, Samoa in 1883, Queensland in 1886, and Bombay and Zanzibar in 1887. In Malaysia, cocoa was introduced in 1778; In Hawaii in 1831, and in India in the 20th century (Nair, 2010).

3. Cocoa varieties

The main varieties of cocoa are Forastero, Criollo, and Trinitario. The unripe pods of Forastero variety are green and yellow during ripening. It gives high yield and takes 5–6 days for fermentation. Forastero variety is the most commonly used, compromising 95% of the world production of cocoa, but the quality is poor. Recently, Brazil and West Africa planted Forastero in large areas. Amelonados is another well-known predominant type of Forastero, traditionally cultivated in West African countries since 19th century. It is self-compatible, shows wide genetic variability and used for breeding in the major cocoa producing countries (FAO, 1977; Nair, 2010). The ripe Criollo pods are red or yellow and seeds are large, get fermented quickly. It is considered as high quality and delicious cocoa beans compared with Forastero, but the yield is found to be poor. It dominated the world cocoa market in the 18th century. The major demerit of Criollo variety is low content of cocoa fat compared with Forastero variety. Moreover, it tends to be less resistant to varieties of diseases that attack the cocoa plants. Only few countries are still producing Criollo beans, among them Venezuela is the largest producer. Trinitario is a hybrid (mix of Criollo with Forastero) high quality variety, has higher yield and is more resistant to diseases than the others (Yanamoto et al., 1995). It was planted in Trinidad and then spread to Venezuela, Ecuador, Cameroon, Samoa, Sri Lanka, Java, and Papua New Guinea. To improve the quality and yield, new cocoa hybrids called Series II hybrids have been developed from crosses between Amazon, Trinitario, and Amelonado genotypes (Adu-Ampomah and Sersah, 1987/1988). These hybrids have already been grown by farmers (Adu-Ampomah, 1996). Currently, these new hybrids are not commercially used, but they will be introduced in the near future. Moreover, the major nutrients such as antioxidants and phenolics level in these hybrids have been well acknowledged by Jonfia-Essien et al. (2008). Furthermore, the authors also reported that the new hybrid beans show significant antioxidant capacities than the traditional beans. The new cocoa hybrids have also been reported to have exhibited resistance to pest damage during storage.

4. Cocoa production

The major cocoa beans growing countries in the world are Ivory Coast, Ghana, Indonesia, Cameroon, Nigeria, Brazil, Ecuador, Dominician Republic, and Malaysia, contributing almost 90% of world production (ICCO, 2009/2010; FAO, 2012). The world total cocoa beans productions in season 2007/2008 to 2009/2010 are shown in Table 1. The Global cocoa beans production declined at 3.613 million tonnes in 2009/2010 season, while in 2007/2008 it was 3.752 million tonnes (Table 1). In season 2007/2008 to 2009/2010, the cocoa beans production declined by 3% in Africa, while it increased by 1.9% and 1.8% in the Americas and in Asia and Oceania to 14.4% and 17.5% respectively. However, Africa is still the largest cocoa producing region, contributing 68.0% of the total world production followed by Asia and Oceania and the Americas in 2009/2010. In Malaysia, cocoa beans production has also declined gradually. According to the Malaysian Cocoa Board, cocoa beans production in 2011 was 15,000 tonnes, while in 2007 it was 35,180 tonnes (MCB, 2011). The International Cocoa

Table 1
Production of cocoa beans in the World (thousands of tonnes).

	2007/2008		2008/2009		2009/2010	
Africa	2693	71.8%	2518	69.9%	2458	68.0%
Ivory Coast	1382		1222		1242	
Ghana	729		662		632	
Nigeria	230		250		240	
Cameroon	185		227		190	
Others	166		158		154	
America	469	12.5%	488	13.5%	522	14.4%
Brazil	171		157		161	
Ecuador	118		134		160	
Others	180		197		201	
Asia and Oceania	591	15.8%	599	16.6%	633	17.5%
Indonesia	485		490		535	
Papua New Guinea	52		59		50	
Others	55		50		48	
World total	3752	100.0%	3605	100.0%	3613	100.0%

Source: ICCO Quarterly Bulletin of Cocoa Statistics, vol. xxxvi, no. 4, Cocoa year 2009/2010.

Please cite this article in press as: Jahurul, M.H.A., et al. Cocoa butter fats and possibilities of substitution in food products concerning cocoa varieties, alternative sources, extraction methods, composition, and characteristics. Journal of Food Engineering (2012), http://dx.doi.org/10.1016/j.jfoodeng.2012.09.024