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Review

Cocoa shell and its compounds: Applications in the food industry

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ABSTRACT

Background: Cocoa shell is removed from the cocoa bean before or after the seeds are roasted; it is considered a by-product of the cocoa industry that is usually underutilized or considered waste. Some studies and patents have been developed in order to give a nobler destination to this material. Interest in cocoa shell is due to its high nutritional value owing to the presence of a variety of biocompounds, such as phenolic compounds, dietary fibers, theobromine and a lipid profile similar to that of cocoa butter, besides its chocolate color and flavor.

Scope and approach: In this review, a characterization and evaluation of cocoa shell and its bio-compounds is discussed, as well as its health effects, methods for determining the main compounds, and recent applications of this by-product as a food ingredient.

Key findings and conclusions: The main application of cocoa shell in the food industry is as a source of fiber. However, studies have shown that this material has a high content of phenolic compounds, showing itself to have potential application as an antioxidant agent. Cocoa shell proves to be a promising ingredient in the food industry, but there have been few studies devoted to this by-product, indicating that it is a raw material with great potential for exploration.

1. Introduction

Cocoa (Theobroma cacao L.) is the name given to the fruit of the cocoa tree. Its seeds are commonly called cocoa beans and consist of an outer shell or testa surrounding two cotyledons and a small germ (Fig. 1).

The main producing countries of cocoa beans are Côte d'Ivoire, Ghana, Indonesia, Nigeria, Ecuador, Cameroon, and Brazil, contributing almost 90% of the world's total production. World production of cocoa beans in the 2013/2014 harvest was 4372 thousand tons, and it is estimated that for the 2014/2015 harvest, there will be a reduction of approximately 3.2%, as can be seen in Table 1 (International Cocoa Organization, 2016). Indeed, following the trend of recent years, production has decreased as opposed to consumption, which, according to Jonfia-Essien, West, Alderson, and Tucker (2008), has increased over the last decade.

The cocoa shell is removed together with the germ before or after roasting and the broken fragments of cotyledon, called nibs, free of the shell, are used in chocolate production (Beckett, 2008, 2009). Cocoa shell is considered an industrial by-product of cocoa production that is usually underutilized or considered waste, and is mainly used as fuel for boilers (Arlorio et al., 2005; El-Saied, Morsi, & Amer, 1981; Fowler, 2009), although there are applications in animal feed and fertilizer preparation (Ntiamoah & Afrane, 2008; Prasad, Simmons, & Maher, 2004).

The presence of cocoa shell in products that are made from cocoa beans is undesirable as it adversely affects the process and final product quality. In this way, the shell content of cocoa products is an important quality parameter. In this context, the European Union directive on cocoa and chocolate has established the level of shell, including germ, in cocoa nibs up to 5%, related to the fat-free dry cocoa content (EEC, 2000). Levels higher than this value should be regarded as a value-reduction factor. Interestingly, the Codex Alimentarius has, for the time being, maintained that limit. Therefore, this quality criterion of cocoa raw materials depends on national legislation (Hug, Golay, Giuffrida, Dionisi, & Destaillats, 2006).

It is estimated that cocoa shell production is very significant, since it represents 12%–20% of the cocoa seed (Mendes & Lima, 2007). Considering the world production of cocoa beans, the world generation of this waste can be calculated at approximately 700 thousand tons, which is a substantial amount (International

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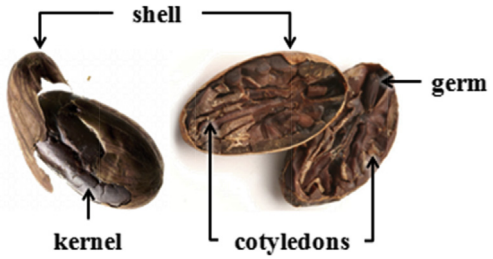

Fig. 1. Parts of cocoa beans.
adapted from Robert (2012)

Cocoa Organization, 2016). However, when we think of the shelling waste, this amount could be even higher if we consider that along with the shell the germ and possibly part of nibs that are attached to the shell are removed.

Recently, the value of agricultural by-products, such as the cocoa shell, has received increasing attention due to the scarcity of natural resources and serious environmental problems. Many researchers propose the use of these by-products in applications such as food ingredients or other value-added applications (Jahurul et al., 2013; Yusof, Khanahmadi, Amid, & Mahmod, 2016). Thus, a further exploration of these products as additives in foods or supplements of high nutritional value has gained increasing interest, primarily due to their nutritional characteristics and secondly, to the fact that their recovery can be economically attractive (Murthy & Naidu, 2012).

Lately, some studies and patents have been developed, suggesting alternative applications for this material, as it is a green material containing very interesting compounds from a nutritional point of view, such as phenolic compounds, fibers, and a significant fat content with a very interesting lipid profile, very similar to that of cocoa butter (Arlorio, Coisson, Restani, & Martelli, 2001; Arlorio et al., 2005; Borchers, Keen, Hannum, & Gershwin, 2000; El-Saied et al., 1981; Martínez et al., 2012). Conversely, this material can also present some components that need to be carefully studied, as they are potentially toxic, such as mycotoxins and theobromine (Adamafio, 2013; Brunetto et al., 2007; Copetti, Pereira, Iamanaka, Pitt, & Taniwaki, 2010; Copetti et al., 2012).

Thus, the present study aims to deepen the existing knowledge about the cocoa shell and its main compounds in order to verify their potential use in the food industry.

2. Cocoa bean processing and its by-products and wastes

The processing of cocoa beans takes place in two stages, known as preprocessing and processing. The first comprises the steps carried out in the field by the cocoa producer, such as harvesting, fruit opening, removal of the seeds with the pulp, fermentation, drying of the beans, and storage. The process usually used in industry comprises the second phase and involves obtaining the ingredients used for the manufacture of chocolate and derivatives (Beckett, 2009; Gomes, 2007). All steps involved in cocoa preprocessing and processing and the generated products and byproducts, may be observed in the flowchart shown in Fig. 2.

In the processing of the product, the first step is cleaning, to remove most of the impurities (Beckett, 2008; Dand, 1993). After cleaning of the beans, depending on the industry in which the beans are processed, they can follow two different industrial processes, both of which result in the same final product: cocoa mass. In some industries, the cocoa beans are subjected to a thermal pretreatment, followed by breaking, shelling, and winnowing and only later to roasting; in other units, the whole beans are roasted along with the shells, being subjected to subsequent shelling.

The removal of the shell is an important step in the process of obtaining the cocoa mass as some countries present legislation that determines the maximum value at which this residue may be present in cocoa mass. In addition, to meet legal requirements, adequate removal of the shell is an important prerequisite for obtaining good quality product once the shell is exposed to external factors that allow the appearance of undesirable contaminants. These compounds do not positively contribute to the flavor and taste of the final product and may also be responsible for off-flavor. Additionally, shells are fibrous materials with extremely high strength, a fact that can make the grind difficult and may cause abrasion to the equipment. In addition to these factors, an effective separation of shells and nibs influences the efficiency of the process, the loss of small nib particles along with the shell being financially undesirable. Ideally, in the shelling step, the shell must be separated perfectly, releasing large parts of shells and the nibs left practically intact (Beckett, 2009; Dand, 1993).

The configuration that comprises thermal pretreatment with subsequent removal of the shell offers two major advantages. The first is that water evaporates from the beans, with a puffing effect, and heat increases the brittleness of the shell, making its later removal easier. The second advantage is that thermal pretreatment

Table 1
World production of cocoa beans.

	Harvest 2013/2014		Estimates 2014/2015	
	Thousand tones	Percentage (%)	Thousand tones	Percentage (%)
Africa	**3199**	**73.2**	**3068**	**72.5**
Cameroon	211	4.8	232	5.5
Côte d'Ivoire	1746	39.9	1796	42.5
Ghana	897	20.5	740	17.5
Nigeria	248	5.7	195	4.6
Others	97	2.2	105	2.5
America	**726**	**16.6**	**760**	**18.0**
Brazil	228	5.2	230	5.4
Ecuador	234	5.4	250	5.9
Others	264	6.0	280	6.6
Asia & Oceania	**447**	**10.2**	**401**	**9.5**
Indonesia	375	8.6	325	7.7
Papua New Guinea	36	0.8	36	0.8
Others	36	0.8	40	0.9
World Total	**4372**	**100**	**4230**	**100**

adapted from International Cocoa Organization (2016)