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Review

Properties of Brazil nuts: A review

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Brazil nut is a seed with high nutritional value and of great economic importance to the Northern region of Brazil. In addition to enabling direct consumption, its nutritional potential enables the development of various products. Among its nutrients, emphasis is given to the amino acid-rich proteins, lipid content and selenium, which exhibits antioxidant properties. This review addresses the nutritional value and approaches different technologies applied in the Brazil nut products process.

Key words: *Bertholletia excelsa*, selenium, oleic acid.

INTRODUCTION

Brazil nut (*Bertholletia excelsa*, Bonpl.), a plant in the family of Lecythidaceae, is native to the Amazon rain forest and adjacent areas in Brazil, Bolivia, Peru (Ferreira et al., 2011). It is an extractive product with high ecological, social, economic and nutritional value (Silva et al., 2010). It is considered a good nutritional source for food enrichment and production as an alternative ingredient for some consumer groups (Yang, 2009). The kernels contain about 60 to 70% lipids, 15 to 20% protein, sulfur, vitamin E and antioxidant properties (Martins et al., 2012). The largest part of its production comes from areas of extractive activities, that is, they are collected from the natural forest; the seed is processed in plants by dehydration to obtain the dehydrated kernel (safe humidity below 15%) to be processed in-shell or shelled. Figure 1 shows a flowchart of Brazil nut production. The nuts that do not meet the size standards (small, medium and large) or have undesirable characteristics (color, shape or stains) according to industry standards can be otherwise used in pieces and/or for the production of other products, such as oil, or as ingredients to add to cereal bars and cookies (Cardarelli and Oliveira, 2000). Figure 2 shows the different classifications of Brazil nut used by the processing industry. The Brazilian production has two different purposes in terms of trade: domestic consumption and export. These rates have changed, and today export accounts for 25 to 30% and domestic consumption accounts for 70 to 75% of national production. Some of Brazil nut importing countries are Bolivia, United States (including the processed nuts),

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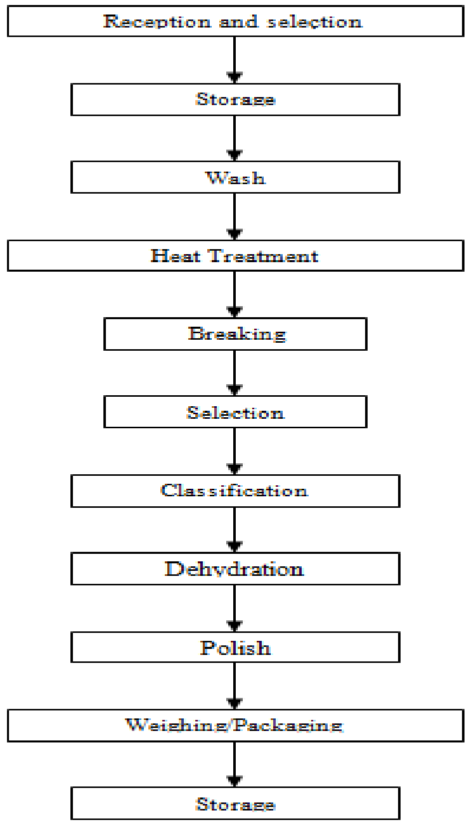

Figure 1. Process flowchart for shelled and unshelled nuts. Source: PACHECO; SCUSSEL, 2006.

Figure 2. Different classifications of Brazil nut used by the processing industry: (a) large, (b) medium and (c) midget.

Hong Kong, Australia and several European countries. The objective of this manuscript was to bring relevant information about the nutritional and technological properties involving Brazil nuts. This way, the study was divided as follows: an overview on nutritional aspects and Brazil nut products, including oil, cake and flour, milk extract and extruded products.

NUTRITIONAL ASPECTS

Brazil nut has high content of proteins, carbohydrates, unsaturated lipids, vitamins and essential minerals. The average content of lipids (60-70%) contributes to its high caloric content, and the ratio of saturated, mono-unsaturated and polyunsaturated fatty acids is 25:41:34 (USDA, 2008). These data show that the content of unsaturated fat in the Brazil nut is higher than that of any other nut. Brazil nuts are a good source of vitamin E (Da Costa et al., 2011) and of essential amino acids (Ampe et al., 1986; Souza and Menezes, 2004; Silva et al., 2010). It is also a source of micronutrients, especially selenium (Se), phytosterols, tocopherols, squalene, and phenolic compounds; all of them are associated with potential health benefits. Furthermore, the FDA has approved the following health claim and disclosure statement: "Scientific evidence suggests", but does not prove, that eating 1.5 ounces per day of most nuts, such as Brazil nuts, as part of a diet low in saturated fat and cholesterol may reduce the risk of heart disease (FDA, 2008)." Beta- and gamma-tocopherols are the most abundant tocopherol isomers present in Brazil nuts. The contents of alpha- and gamma-tocopherol in Brazil nuts are 72.55 and 74.35 mg/g of oil, respectively, and the contents of beta-sitosterol, campesterol and stigmasterol are 79.00, 4.00, and 11:33 mg/g of oil, respectively (Costa et al., 2010). Compared to other tree nuts, Brazil nuts are known as the best source of Se (Chunhieng et al., 2004; Pacheco and Scussel, 2007; Chunhieng et al., 2008; Welna et al., 2008). Furthermore, it also contains numerous vital minerals such as calcium, magnesium, phosphorus, and potassium (USDA, 2008; Yang, 2009). Adequate intake of Se is essential for normal activity of numerous selenoenzymes involved in the protection against oxidative stress, maintenance of redox status and regulation of the immune system and thyroid function (Reeves and Hoffmand, 2009). This element can also protect against prostate, lung, and liver cancers due to its high levels of phytonutrients (Yang, 2009). Thomson et al. (2008) demonstrated that 100 µg/day of Se (equivalent to two nuts), for three months increased plasma selenium concentrations and glutathione peroxidase in healthy subjects. Gonzalez and Salas-Salvado (2006) suggested that the risk of developing chronic diseases was reduced with regular consumption of Brazil nuts, and it increased the body’s ability to regulate hormone levels. Furthermore, animal experiments, cell culture and observational studies indicate that antioxidants can prevent the development of cancer and cardiovascular disease (Kris-Etherton et al., 2001). In another study, Stockler-Pinto et al. (2009) reported that the ingestion of a single serving of Brazil nut (5 g) a day for three months is effective in increasing the concentration of Se and glutathione peroxidase activity thereby improving the antioxidant capacity in patients with disabilities in that capacity. The consumption of only one nut increases the concentration of Se and glutathione peroxidase activity (Cominetti et al., 2010). In addition to the kernel, the seed coat from different geographic origins showed an average content of Se of 6.34 to 20.58 mg/kg (Manfio et al. 2012). Other minerals such as barium (Ba) and radium (Ra) can also be found in Brazil nuts (Martins et al. 2012). The varied levels of Ra in the nuts seem to be influenced by bioaccumulation in the tree, which is transferred to the seeds depending on the concentration of Ra in the soil that is absorbed by the tree. Consequently, the concentrations of Se and Ba in the nuts can vary (Parekh et al., 2008). Tables 1 and 2 shows the major nutrients and minerals present in Brazil nut.

BRAZIL NUT PRODUCTS

Despite of in-shell or shelled Brazil vacuum packaged for sale, the thin brown “skin” covering the seed, is rich in protein, lipids, and selenium. It is obtained as a waste product resulting from processing, but due to the antioxidant potential seems to have the potential to be used as a dietary supplement. In addition, it can be tested in the biotechnology field to obtain enzymes with industrial potential. Among the products obtained from industrial processing of whole nuts or pieces of nuts are oil and cake (partially or fully defatted) obtained by nut pressing and/or by extracting the fatty material (Souza and Menezes, 2004). The oil can be obtained by extraction using n-hexane and ethanol, and it can be used in food or in cosmetic formulations (Freitas et al., 2007). An extract, also called milk, is obtained from the cake by dilution in hot water followed by centrifuging. This milk is intended for culinary use, especially for lactose intolerant individuals. Extrusion is another industrial process used to obtain food. This technique converts a solid material to liquid by combining moisture, heat, compression and shear stress promoting starch gelatinization forcing their passage through a matrix (Borba et al., 2005). Snack foods, animal feed, cereals, etc. are produced by this process. This review describes some Brazil nut products and the processes and technologies used to obtain them.

Oil

Brazil nut oil can be used in cosmetics, foods and

Table 1. Brazil nut proximate composition by different authors.

Proximate composition	Almeida (1963)	Andrade et al. (1999)	Souza and Menezes (2004)	Venkatashalam and Sathe (2006)	Moodley et al. (2007)	USDA (2008)	Felberg et al. (2009)
Calories (Kcal)	666.0	-	676.5	-	-	-	-
Lipids (g%)	65.9	66.8	67.3	66.7	66.8	69.0	70.62
Protein (g%)	14.40	13.60	14.29	19.93	13.60	18.0	14.35
Carbohydrates (g%)	11.00	10.30	3.42	0.69	10.30	13.0	11.61
Fiber (g%)	2.10	-	8.02	-			-

Table 2. Minerals in Brazil nut according different authors.

Component[a]	Furr et al. (1979)[b]	Andrade et al. (1999)	Gonçalves et al. (2002)[c]	Chunhieng et al. (2004)	Ferberg (2004)	Moodley et al. (2007)[b]	Yang (2009)	Naozuka et al. (2010)	Silva et al. (2010)
Calcium	1592	132	206.75	6060	159.04	7432.8	7432.8	-	205
Copper	1.9	1.3	1.17	-	2.22	59.44	59.44	11.0	1.35
Iron	93	3.4	9.67	80	2.82	74.26	74.26	18.3	-
Phosphorus	1.7	674	564.50	23800	721.25	-	-	-	563
Magnesium	3370	160	312.50	13380	381.90	9678.5	9678.5	-	310.10
Manganese	8	0.6	6.85	50	1.34	3.4	3.4	5.02	5.99
Potassium	5405	644	514.75	19690	717.25	-	-	-	512.70
Zinc	41	3.5	7.1	115	4.72	110.31	110.31	92.8	6.90

[a]mg%, [b]retail packaging, [c]origin: trees near Manaus (AM) Brazil.

pharmaceuticals. The oil can be extracted by mechanical or hydraulic press or by using reagents or CO_2 (Neto et al., 2009). Hot or cold pressed extractions are the most commonly used methods for the extraction of oils from most oilseeds at an industrial scale.

In a laboratory scale, solid-liquid extraction is commonly used with solvents such as ethanol and n-hexane (Santos et al., 2012). The difficulties related to oil recovery and the possibility to damage the oil and the cake, due to the temperature increase that occurs during pressing, emphasize the need to develop low temperature extraction methods (Guedes, 2006). Supercritical CO_2 extraction can be used as an alternative method to degrease Brazil nut (Penedo et al., 1997; Rodrigues et al., 2005).

The composition of the Brazil nut crude oil shows high content of unsaturated fatty acids, 36.21 to 51% of monounsaturated oleic fatty acid, and 34 to 38.28% of oleic fatty acid (Silva et al., 2010; Ferreira et al., 2006). According to Silva et al. (2010), the oleic fatty acid is the main component of almond oil, but Brazil nut is also a source of polyunsaturated fatty acids (Silva et al., 2010; Ferreira et al., 2006; Gonçalves et al., 2002). Saraiva et al. (2009) found linoleic acid levels between 30 - 47%. Funasaki et al. (2012) argue that due to the fact that Brazil nut oil is rich in unsaturated fatty acids, which are sensitive to oxidation, the rate of oxidation should be monitored since it is an important quality parameter. The main fatty acids found are shown in Table 3.

"Cake" and flour

The brown residue obtained by extracting the kernel oil, generally called "cake", has aroused great interest among researchers given its high protein content (Gloria and Regitano - D'arce, 2000). According to Ferreira et al., (2006), the cake, besides containing on average 19.17% lipids, 28.34% protein, and 39.63% carbohydrates, it is also an excellent source of Se.

Souza and Menezes (2004) found 0.714 mg Se/100 g of cake, which is 3.56 times higher than the content of Se found in the Brazil nut kernel (0.204 mg /100 g). This difference can be explained by the large number of kernels with their skin that are generally used to obtain the cake and also by its lower lipid content, suggesting that the kernel skin may contain high concentrations of selenium (Berno et al., 2010). The "cake" is considered an excellent source of vegetable protein due to its richness in sulphur amino acids, methionine and cysteine, which are usually missing in other vegetable proteins (Cohen et al., 2007).

Table 3. Major fatty acids present in crude oils from the nuts of Brazil, according to different authors.

Component (acids)	Gonçalves et al. (2002)	Ryan et al. (2006)	Ferreira et al. (2006)	Venkatachalam and Sathe (2006)	Freitas et al. (2007)	Chunhieng (2008)	Yang (2009)	Silva et al. (2010)	Santos et al. (2012)
Palmitic (C16)	13.15	13.5	13	-	13.8	13.0	13.5	13.33	14.24
Stearic (C18)	10.36	11.77		9.51	10.36	11.0	11.77	10.78	11.19
Oleic (C18:1, W-9)	37.42	29.09	51	28.75	31.4	39.3	29.09	36.21	36.26
Linoleic (C18:2,W-6)	37.75	42.80	34	45.43		36.1	42.8	38.28	37.53
Linolenic (C18:3, W-9)	-	0.20	-	0.18	42.5		0.20	-	0.076

Experiments conducted on rats have shown that the flour obtained in the process has higher quality than soy flour and lower quality than casein flour powder. The “cake” has numerous possibilities for application focusing on the enrichment of a wide variety of food groups, such as baked goods, beverages, sausages, flour, milk, cereals, chips and crackers, sweet and savory treats, pastry, ice cream, chocolates, and many others (Souza and Menezes, 2004).

"Milk" extract

The nut "milk" is obtained by shelling fresh nuts, which are then shredded producing a thick white extract (popularly called milk) and are subsequently diluted in water. This product is similar to coconut milk; it is rich in protein and is used as an ingredient in foods (Pacheco and Scussel, 2006). According to Cardarelli and Oliveira (2000), when the cake is diluted in water, the "milk" is produced, which after being pasteurized and refrigerated remains stable for approximately 30 days. These authors found that its additive effect, pasteurization, cooling and the addition of preservatives extended its shelf life to 180 days. Felberg et al. (2002) evaluated the effects of extraction conditions on the yield and quality of dehulled Brazil nut extract. In the disintegration step, four different temperatures (25, 50, 75 and 100°C) were evaluated in one or two extractions. The experimental samples obtained were evaluated for composition, extraction yield and sweetness (sensory analysis). The nut "milk" obtained at 75°C with one and two extractions showed solid, oil and protein yield significantly higher than those obtained under the other temperatures studied. As for the sugar content, different concentrations (2, 3 and 4%) were evaluated and subjected to sensory analysis. The "milk” obtained at 75°C and formulated with 3% sugar was preferred by the majority of the panel (78%). Felberg et al. (2004) formulated a mixed drink of whole soy extract and Brazil nut extract resulting in a drink of high nutritional value. The soy extract drink was formulated with 3% sugar, 0.2% salt, and different concentrations of Brazil nut extract (10, 20, 30, 40, and 50). The whole soy drink formulated with 40% of Brazil nut extract, 3% sugar, and 0.2% salt was accepted by most of the panel.

EXTRUSION

Extrusion technology has become a major process for the development of food products. This process can be done using hot or cold materials and it combines several unit operations including mixing, cooking, kneading, shearing, forming and shaping. Hot extrusion is a high-temperature short-time process, which reduces microbial contamination. On the other hand, in the cold extrusion process, the product is extruded without cooking or distortion of the food (Fellows, 2006). Extrusion promotes starch gelatinization, denaturation and re-orientation of proteins, enzyme inactivation, removal of some toxic substances, and the reduction in microbial counts (Borba et al., 2005; Menegassi et al., 2007). This technology is used to produce instant drinks, modified starches for industrial use, precooked animal feeds, ready-to-eat snacks, precooked cereal flakes, semi-processed sauces, bakery products, and breakfast cereals among others (Souza and Menezes, 2008a). Thermoplastic extrusion stands out in food technology for its versatility, high productivity, low cost, and for not generating waste during or after processing.

According to Souza and Menezes (2008b), this technology is the process by which the mechanical friction is combined with thermal heating to mix, plasticize and gelatinize the starch, leading to its fluidization, in order to obtain products with new textures and shapes. Extrusion confers a beneficial effect on the quality of products since it enables the mixing of different raw materials and other nutrients (Carvalho et al. 2010). Souza and Menezes (2006) evaluated the overall acceptance, flavor, crispness, and purchase intent of sweet, salty, and natural extruded cereals made from Brazil nut cake mixed with cassava after six months of storage at ambient temperature. The results showed that these three types of breakfast cereals obtained higher scores in all attributes evaluated than those of a similar commercial cereal. The sweet cereal received higher scores than those of the natural and salty cereals. Souza and Menezes (2008a) conducted a study aimed at finding the ideal formula of Brazil nut and cassava flour mixture processed by extrusion in order to obtain a product rich in vegetable protein ready for consumption. They found that the formulations containing higher amounts of nuts were more expanded, had light-color and higher contents of protein, lipid and ash. On the other hand, formulations with lower amounts of nuts did not expand, had grayish color and had higher content of carbohydrates. In a study on the optimization of the processing conditions of thermoplastic extrusion of a mixture of Brazil nut cake and cassava flour as a function of acceptance, Souza and Menezes (2008b) found that by increasing the Brazil nut content, temperature and moisture, global acceptance and purchase intent also increased. Furthermore, Brazil nut cake at very high and/or very low temperature and moisture (extreme levels) can lead to reduce global acceptance scores and purchase intent of the products. The highest global acceptance and purchase intent scores found in that study are in the central points and indicate the validity of the model.

FINAL CONSIDERATIONS

Brazil nut has significant nutritional properties that can help the prevention of certain chronic diseases such as heart disease and cancer. It is a recognized source of selenium, and is rich in unsaturated fatty acids and essential amino acids. The products derived from Brazil nut can be used as raw material for the production of various products increasing their nutritional value.

Conflict of interests

The authors did not declare any conflict of interest.

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