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# Chemical characterization, nutritional aspects and antioxidant capacity of noni (*Morinda citrifolia* L) produced in northeastern Brazil

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**Abstract**

Noni (*Morinda citrifolia* L.) is a kind of fruit introduced in Brazil, with a strong commercial appeal that is consumed in several Brazilian regions, due to functional benefits. This work aimed to evaluate the chemical composition and nutritional properties of noni's pulp and seeds cultivated in Maranhão. Food composition of pulp and seeds differed from fruit cultivated in other regions of Brazil. In pulp, the ascorbic acid content was the most significant (117.33 mg. 100. $g^{-1}$). In the seeds, the total fibers were the higher nutrient found (36. 97 g. 100 $g^{-1}$). In relation to nutritional aspects, the pulp showed an important nutritional profile, with high vitamin C, manganese, magnesium, calcium and iron contents in 30 g of sample, exceeding 30% of daily recommended intake (DRI), according to ANVISA. Seeds presented high total fibers contents (5 g) for portion. Fibers and manganese may be considered constituents sources, where manganese provides, at least, 24% of DRI for this mineral. Results showed that seeds presented higher percentage of free radical scavenging (FRS) and pulp possesses higher total phenolic contents (TPC) and antioxidant capacity by DPPH method. On the other hand, skins presented higher antioxidant capacity by FRAP method.



## Introduction

Popularly known as noni, *Morinda citrifolia* L. belongs to the Rubiaceae family. It can be found in several parts of the world, especially in tropical regions of Africa, Central and south America, Caribe, in countries as Australia, China, Malaysia, Indonesian and India (Yashaswini *et al.*, 2014). Noni has been used in popular medicine in Polynesia for more than 2.000 years due to several therapeutic effects, including antibacterial, antiviral, antifungal, antitumor, anthelmintic, analgesic, besides presenting anti-inflammatory effects and can contributes to immune system (Ulloa *et al*. 2014).

This fruit is considered a natural antioxidant and the daily consumption of its juice helps the immune system and increases the cells capacity of absorption (Silva *et al*., 2013). Noni can be found as pasteurized or fermented juice, powder, capsules and others. Currently, it has been considered the supplement of low calorie most important negotiated in the international market (Yashaswini *et al.*, 2014).

Due to increasing consumption and commercialization, the brazilian Legislation prohibited the commercialization of noni's products in Brazil, claiming that the scientific evidences do not prove it's safety for use as food (ANVISA, 2007). Chemical composition and nutritional properties of noni's pulp and seeds can change according to environmental and genetic factors, geographic distribution and mature stages. Therefore, it's important to study noni's composition cultivated in different brazilian regions (Correia *et al*., 2011). There are several researches that determined chemical and/ or proximal composition, bioactive compounds contents and antioxidant activity of noni's pulp and seeds cultivated in Roraima, Ceará, Rio Grande do Norte, Piauí and Mato Grosso (Canuto *et al*., 2010; Correia *et al.* , 2011; Silva *et al*., 2012; Costa *et al*., 2013; Silva *et al*., 2013; Faria *et al.*, 2014). However, studies about nutritional aspects as the total, soluble and insoluble fibers, as well as minerals profile are scarce. Therefore, this study aimed to evaluate the chemical composition, nutritional properties and antioxidant capacity of noni's pulp and seeds cultivated in Maranhão, Northeastern Brazil.

## Materials and Methods

### *Raw material*

The cultivation of *Morinda citrifolia* L. was conducted in an experimental area of Federal Institute of Maranhão - IFMA, Campus Zé Doca (Latitude:

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3°15 ‘25” South Longitude: 45°39’0” West), in Zé Doca, Maranhão, Brazil. The ripe fruit was harvested and washed with water to remove superficial dirts. The selected fruit was sanitized in solution containing 200 mg. $L^{-1}$ of sodium hypochlorite for 15 minutes. After that, fruits were washed with distilled water and dried. Noni was peeled and seeds and pulp were both manually separated. Seeds were dried for 48 hours at room temperature (30°C), and blended.

*Chemical analysis*

Moisture, ash, protein, lipids, soluble and insoluble fibers contents were determined according to Adolfo Lutz Institute (2008). The moisture determination was based on the drying kiln (SOLAB, Model SL 102) to 105°C; proteins were quantified by the total nitrogen determination (classical method of Kjeldahl), using the conversion factor of 6.25 in nitrogen distiller (TECNAL, model TE-0363); ash was determined by incineration in muffle (FORNITEC) at 550-570°C; the lipid analyzes were performed according to the Soxhlet method in Soxhlet apparatus (TECNAL, TE-044 model). The total carbohydrate content was determined by difference, on a dry basis, according to AOAC (1990), using Equation (1):

$$CT = 100\% - (U + F + P + C) \qquad (1)$$

Where:
TC = total carbohydrates; (%); L = lipids (%); P = protein (%) = F C = crude fiber and ash (%).

The total dietary fiber content was estimated considering soluble and insoluble fibers. The total carbohydrates content was calculated by difference, according to ANVISA (2003b). The total energetic value was determined using traditional conversion factors of 4 kcal. $g^{-1}$ for carbohydrate and protein and 9 kcal. $g^{-1}$ for lipids (ANVISA, 2003b).

In pulp, total acidity was performed by titrimetric method. Soluble solids and pH were determined by refractometry and potentiometrically, respectively, according to Adolfo Lutz Institute (2008). The ascorbic acid determination followed according to Strohecker and Henning (1967) methodology. The contents of sodium, magnesium, calcium, iron, manganese and selenium presents in samples of noni’s pulp and seed were carried out by atomic absorption spectrophotometry with flame, according to AOAC (2006).

*Nutritional information*

Nutritional facts of noni’s pulp was determined based on RDC 2003 No 359 – Technician Regulation of Packaged Food Portions for Nutritional Labelling [14] and RDC 2003 No 360 - Technical Regulation on nutrition labeling of packaged foods (ANVISA, 2003b).

*Antioxidant capacity and total phenolics contents (TPC)*

The antioxidant capacity was determined by DPPH (2,2 diphenyl-picrilhidrazyl) and FRAP (ferric reducing-antioxidant power) assays. For extraction procedures, samples (1 g) were macerated and taken to an erlenmeyer with 25 mL of solvent (acetone:ethanol:water, 40:40:20 v/v/v) and stirred in a shaker at room temperature and 3500 rpm (1509 g) for 1 hour, in the dark. Then, they were filtered under vacuum by sinter funnel. The filtration residue was re-extracted in 15 mL of the same solvent. The filtrates were taken to a volumetric flask to 100 mL with distilled water and used to determine their antioxidant capacity.

DPPH assay followed according to Rufino *et al.* (2010). The extracts (150 µL) were mixed with 2.85 mL of 0.06 mM $DPPH^*$ and shaken in a vortex for 30 seconds. After that, were left to stand at 1 hour in dark, and analyzed using a spectrophotometer at 517 nm (Spectrophotometer Model NOVA 2000 UV, São Paulo, Brazil). The results were expressed in free radical scavenging (%) and µM of Trolox equivalent per gram of dry weight (µM TE. $g^{-1}$). Free radical scavenging was determined and expressed in percentual (%FRS) according to Equation 2.

$$\% FRS = \frac{(Abs_B - Abs_A)}{Abs_B} \times 100 \qquad (2)$$

The analysis of FRAP was performed according to Thaipong *et al.* (2006). 90 µL of extracts were diluted in distilled water (270 µL) and reacted with 2.7 mL of FRAP. The mixture was shaken and taken to a water bath at 37 ºC for 30 min in the dark. The absorbance was taken at 595 nm and expressed as µM of Trolox equivalent per gram of dry weight (µM TE. $g^{-1}$).

Total phenolics contents (TPC) were obtained according to Swain and Hillis (1959) with slightly modifications. 1 mL of extract was mixed with 10 mL of distilled water and 1 mL of 0.25 N Folin–Ciocalteu reagent. After 3 min, 1.5 mL of $Na_2CO_3$ 10% was added and the mixture stood at room temperature (25±1ºC) for 2 hours in the dark. The absorbance was taken at 725 nm, and the results were expressed as mg of gallic acid equivalents (GAE).

*Statistical analysis*

All analysis were performed in triplicate and the results were expressed as mean and then standard deviation (SD).

## Results and Discussion

### *Chemical and proximal composition*

In general, the proximal composition of noni's pulp determined in this study (Table 1) is close to the other results reported by other scientific studies with other fruits cultivated in different brazilian regions (Correia *et al.*, 2011; Costa *et al.*, 2013; Faria *et al.*, 2014). Correia *et al.* (2011) evaluated the proximal composition of noni's pulp cultivated in Ceará, in northern of Brazil, reported 91.9 g. 100 $g^{-1}$ of moisture, 0.63 g. 100 $g^{-1}$ of ash, 0.08 g. 100 $g^{-1}$ of total lipids, 1.06 g. 100 $g^{-1}$ of proteins, 6.32 g. 100 $g^{-1}$ of carbohydrates, 1.76 g. 100 $g^{-1}$ of total fibers and 30.25 kcal. 100 $g^{-1}$ of energetic value. Noni's pulp cultivated in Piauí showed 88.36 g. 100 $g^{-1}$ of moisture, 0.93 g. 100 $g^{-1}$ of ash, 2.24 g. 100 $g^{-1}$ of proteins, 0.37 g. 100 $g^{-1}$ of lipids, 8.37 g. 100 $g^{-1}$ of carbohydrates and 45.7 kcal 100 $g^{-1}$ of energetic value [7]. On the other hand, Faria *et al.* (2014) evaluated noni's pulp from West Central region of Brazil, in the State of Mato Grosso, and verified that the fruit presented 90.66 g. 100 $g^{-1}$ of moisture, 0.66 g. 100 $g^{-1}$ of ash, 0.04 g. 100 $g^{-1}$ of lipids, 2.38 g. 100 $g^{-1}$ of proteins, 1.00 g. 100 $g^{-1}$ of dietary fibers and 5.27 g. 100 $g^{-1}$ of carbohydrates. The materials cultivated in different regions presented discrete differences of moisture, ash, lipids and total fibers contents. However, carbohydrates and proteins contents were different, which can be attributed to different climatic and soil conditions (semi-arid and brazilian cerrado).

Acidity, pH and soluble solids' contents are important markers indicators for the maturation stage of fruit. Comparing the studied samples (Table 1) with those grown in other regions of Brazil, it was found that the values of pH, acidity and soluble solids content's demonstrated in this study were lower than ones reported by Canuto *et al.* (2010) for noni's pulp cultivated in Roraima. The authors found that the soluble solids' content was 9.0°Brix; pH of 4.1 and 3.2% of acidity. To noni's pulp in maturity stage grown in Rio Grande do Norte, Silva *et al.* (2012) reported 10.3°Brix of soluble solids, pH 4.6 and total acidity of 0.39%.

The content of ascorbic acid present in the noni's pulp (Table 1) was 34% lower than ones reported by Silva *et al.* (2012) and Silva *et al.* (2013) (average of 177 mg. 100 $g^{-1}$). On the other hand, it was apparently higher than the level reported by Costa *et al*. (2013). In noni's pulp, the ascorbic acid's content can vary according to the kind of the plant (Silva *et al*., 2013),

Table 1. Chemical and proximal composition of noni's pulp and seeds.

| Parameters | Pulp | Seeds |
|---|---|---|
| Moisture (g. 100$g^{-1}$) | 90.00 ± 0.01 | 28.34 ± 0.01 |
| Ash (g. 100$g^{-1}$) | 0.82 ± 0.01 | 0.60 ± 0.01 |
| Carbohydrates ² (g. 100$g^{-1}$) | 2.68 ± 0.01 | 25.83 ± 0.02 |
| Proteins (g. 100$g^{-1}$) | 4.20 ± 0.01 | 7.47 ± 0.06 |
| Lipids (g. 100$g^{-1}$) | 0.34 ± 0.04 | 0.79 ± 0.03 |
| pH | 3.95 ± 0.07 | 4.50 ± 0.04 |
| Acidity (%) | 0.54 ± 0.02 | 0.28 ± 0.01 |
| Soluble Solids (°Brix) | 8.17 ± 0.05 | - |
| Ascorbic Acid (mg. 100$g^{-1}$) | 117. 33± 0.20 | 24.33± 0.10 |

Data are means ± standard deviation

ripeness stage (Silv*a et al*., 2012) and geographical and environmental factors (Correia *et al*., 2011). Through the comparison between the content of ascorbic acid in noni's pulp and the pulps of other kinds of fruits studied by Freire *et al.* (2012), can be observed that noni's pulp (Table 1) presented lower values than acerola's pulp (778 mg. 100 $g^{-1}$) and cashew's pulp (153 mg. 100 $g^{-1}$). However, noni's pulp presented higher acid ascorbic contents than guava' pulp (69 mg. 100 $g^{-1}$) and strawberry pulp (44 mg. 100 $g^{-1}$). The noni's seeds presented high amounts of total fibers, moisture and carbohydrates, besides 288 kcal. 100 $g^{-1}$ of energetic value (Table 1). Costa *et al.* (2013) reported higher fractions of moisture and carbohydrates for noni's seeds (69 g. 100 $g^{-1}$and 27 g. 100 $g^{-1}$, respectively), and 124 kcal. 100 $g^{-1}$ of caloric value. According to Freire *et al*. (2012) dietary fibers are parts of fruit resistant to digestion and absorption in the human intestine which reduce the risk of several diseases such as dyslipidemias, diabetes and heart diseases.

### *Nutritional informations, minerals and fibers' profile*

Table 2 shows the nutritional information and minerals and fibers' profile to the portion of 30 g of pulp and 15 g of noni's seed. According to the RDC 359/2003, for fruit pulps, the portion and household measure are defined as the sufficient amount to prepare 200 mL of beverage. For noni, to prepare this volume of beverage (200 mL) is necessary a portion of 30 g of fruit's pulp, which corresponded to a household measure of 2 spoons' soup (ANVISA, 2003a).

Among the nutrients with required declaration under Brazilian legislation (ANVISA, 2003b), the lipid content was below the recommended limit (0.5 g per 30 g), and can be considered non-significant in the evaluated products (Table 2). Regarding the

Table 2. Nutritional facts, fibers profile, ascorbic acid and minerals contents of noni's pulp and seeds.

| Nutrients | Pulp | | Seeds | |
|---|---|---|---|---|
| | 30 g | RDI (%)[1] | 15 g | RDI (%)[1] |
| Total Fibers (g)[2] | 0.59±0.02 | 2.40 | 5.55 ± 0.04 | 22.20 |
| Soluble fibers (g) | 0.15± 0.04 | nd | 0.14± 0.02 | nd |
| Insoluble fibers (g) | 0.43±0.03 | nd | 5.41± 0.30 | nd |
| Total energetic value (kcal) | 11.52±0.02 | 0.5 | 43.23±0.01 | 2.20 |
| Na (mg) | 16.65±0.03 | 0.69 | 1.13±0.01 | 0.05 |
| Mg (mg) | 110.49±0.01 | 42.49 | 19.76±0.01 | 7.60 |
| Ca (mg) | 319.61±0.02 | 31.96 | 43.76±0.21 | 4.38 |
| Mn (mg) | 3.00±0.01 | 130.52 | 0.56±0.05 | 24.24 |
| Fe (mg) | 4.21±0.04 | 30.07 | 0.67±0.03 | 4.80 |
| Se (µg) | 25.20±0.01 | 2.24 | ns | ns |

Data are means ± standard deviation
[1]Recommended Daily Intake (ANVISA, 2003b); [2] Total fibers= soluble fibers + insoluble fibers; Amounts per serving of 30 g of pulp and 15 g of seeds; n.s.= not significant; nd: not determined.

recommended daily value (RDV percentage) by RDC 360/2003 (ANVISA, 2003b), the consumption of a portion of noni pulp provided 0.5% of carbohydrates, 1.7% of proteins , 2 4% of fibers , 78.2% of vitamin C and 0.1% of recommended daily value for a diet of 2000 calorie (Table 2). Comparing the recommended daily value supplied by food composition's Table of several fruits (TACO, 2011) to the values obtained in this study, can be observed that the consumption of a portion of noni's pulp can offer lower calories and carbohydrates contents and higher amounts of proteins, when compared to pineapple, açaí, cajá, cashew and mango pulps, for example. Furthermore, the recommended daily value of fat of noni's pulp was higher than other kinds of pulp, except for açaí's pulp.

Overall, noni's pulp presented high contents of vitamin C (recommended daily intake above 30%) (Table 2), as required by RDC number 54/2012 of the brazilian Legislation (ANVISA, 2012). Regarding the minerals' profile, which are more concentrated in the portion were Ca and Mg (Table 2), which act together in vital hormonal activities to the body. Mg is important in many cellular reactions, participating in almost all anabolic and catabolic actions and about 300 enzymatic systems are dependent on this mineral (Amorim and Tirapegui, 2008). Ca is important for bone mineralization, and the needs of this mineral are relatively higher in periods of pregnancy, lactation, adolescence and senescence Naves *et al.*, 2007).

However, considering the daily consumption for minerals, it has been found that a noni pulp portion can be able to provide the highest recommended daily intake (RDI) to Mn (130.52% of RDI), followed by Mg, Ca and Fe (Table 2). The Noni's pulp can be classified as "high content" for Mn, Mg, Ca and Fe, because presents RDI/ portion greater than 30% for each of these minerals (Table 2) as required in the RDC 54/2012 [20].

For seeds, the portion of 15 g was considered (ANVISA, 2003a). According to Table 2, lipid's content of seeds was not significant (Table 2). A portion of seeds showed a high content of FAT (Table 2), which can be classified as "high fiber content" for providing fibers contents higher than 5 g/ portion (ANVISA, 2012). The Institute of Medicine (IOM) recommends a daily intake of fibers of 25 and 38 g for women and men, respectively, between 19-50 years (IOM, 2005). The consumption of approximately 4.5 and 7 portions noni's seeds for women and men (respectively) would attend 100% of the recommendation, contributing to the prevention of cardiovascular diseases and reduction of serum levels of glucose and lipids. Also, it was found that the seeds exhibited 38 times more insoluble fibers than soluble ones (Table 2), fraction that contributes significantly to the increase in stool volume, reduces the transit time in the large intestine, and makes faecal elimination easier and faster (Freire *et al.*, 2012).

As observed for the pulp, seeds presented high minerals contents (Table 2). However, considering the RDI, the consumption of a portion supplied in greater amounts the needs of Mn, followed by Mg, Fe, Ca and Na (Table 2). The seeds can be classified

Table 3. Antioxidant capacity and total phenolic compounds of noni's pulp, seeds and skin.

| Parameters | Pulp | Seeds | Skin |
|---|---|---|---|
| FRS (%) | 14.03±0.58$^b$ | 29.27±0.88$^c$ | 10.22$^a$ ±0.07 |
| DPPH | 348.47±1.83$^c$ | 61.47±1.43$^a$ | 294.96±0.37$^b$ |
| FRAP | 38.07±0$^b$ | 34.79±0.95$^a$ | 57.95±1.82$^c$ |
| TPC | 79.57±0.14$^c$ | 6.1±0.08$^a$ | 61.84±0.07$^b$ |

Data are means ± standard deviation. Values within lines with different letters are significantly different ($p < 0.05$).
DPPH and FRAP are expressed as µM TE.g$^{-1}$ (µM of Trolox equivalent per gram, DW)
TPC- total phenolics contents, mg GAE.g$^{-1}$ (mg of galic acid equivalent per gram, DW)

as "source" of Mn for presenting RDI above 15%, as required by legislation. According to Panziera *et al.* (2011) manganese has significant importance in the mitochondria for being part of two metalloenzymes, pyruvate carboxylase and the Mn-superoxide dismutase. In addition, its deficiency may play a role in hepatic lipid peroxidation, as well as affecting glucose transport and metabolism of adipocyte cells.

*Antioxidant capacity and total phenolics*

The results for antioxidant capacity and total phenolics are presented in Table 3. When expressed in percentual of FRS, seeds presented higher values (29.3%) when compared to pulp and skin (14 and 10.2%, respectively). Pulp showed higher antioxidant capacity (348.5 µM TE. g$^{-1}$ when compared to seeds (61.47 µM TE. g$^{-1}$) and skins (294.9 µM TE. g$^{-1}$) when antioxidant capacity was measured by DPPH method.

FRAP assays showed that pulp and seeds presented 38.1 and 34.8 µM TE. g$^{-1}$ of antioxidant capacity, respectively. These values are according to results obtained by Rodrigues *et al.* (2013) for noni pulp with seeds, ranging of 23.41 to 40.81 µM TE. g$^{-1}$ for different extracts. The skins presented antioxidant capacity (FRAP) of 57.9 µM TE. g$^{-1}$, higher than pulp and seeds.

According to Correia *et al.* (2011) phenolic compounds are related to the flavor, color, shelf-life and activity of the product as a functional food, strongly correlated with the antioxidant capacity. Pulp presented TPC (79.6 mg GAE. 100 g$^{-1}$) in agreement to Costa *et al.* (2013) (12.7 to 109.8 mg GAE. 100 g$^{-1}$). However, Correia *et al.* (2011) and Palioto *et al.* (2015) found higher TPC, of 216 mg GAE. 100 g$^{-1}$ and 306.3 to 1143.5 mg GAE. 100 g$^{-1}$, respectively. Krishnaiah *et al*. (2013) evaluated dehydrated noni's pulp and found TPC of 431.8 mg GAE.100 g$^{-1}$.

We found TPC of 6.09 mg GAE. 100 g$^{-1}$ for noni seeds, consistent to Costa *et al*. (2013) that reported TPC in a range of 2.9 to 28.7 mg GAE. 100 g$^{-1}$ for the same materials. Skin presented TPC of 61.8 mg GAE. 100 g$^{-1}$. Costa *et al*. (2013) found TPC in a range of 8.2 to 76 mg GAE. 100 g$^{-1}$ for noni's skins. Palioto *et al*. (2015) found higher TPC, ranging from 820.8 to 1143.5 mg GAE. 100 g$^{-1}$ for noni's pulp cultivated in South region of Brazil (Paraná).

A studied perfomed by West *et al*. (2008) have reported noni seeds as non-toxic and non-cytotoxic, and according to West *et al.* (2011), natural toxicants were not found in noni extracts nor were any potential antinutrient substance identified. Therefore it is necessary that future studies evaluating the consumption feasibility of these materials are accompanied by toxicological tests to ensure the safety of their consumption.

## Conclusion

Noni's pulp and seeds have great importance in the diet. The pulp presents high contents of ascorbic acid and minerals as Mn, Mg, Ca and Fe, while the seeds are rich sources of fibers and Mn. Pulp presented higher antioxidant capacity measured by DPPH method and total phenolic contents. In contrast, the skins presented higher values of antioxidant capacity for FRAP method, and seeds showed higher FRS percentage. The results of this study showed that noni is a high nutritional value fruit, and all parts can be used and scaled up in the daily diet.

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