



# Obtaining Carotenoids and Capsaicinoids (*Capsicum chacoense*) with a Green Solvent (*Acrocomia aculeata* Almond Oil) <sup>†</sup>

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**Abstract:** *Capsicum chacoense* (wild red pepper) and *Acrocomia aculeata* almond (Paraguayan coconut) are fruits native to Paraguay which are little-used and can be sources of important bioactive compounds. The aim of this work was to evaluate the use of Paraguayan coconut kernel oil as a green solvent for the extraction of carotenoids and capsaicinoids from wild red pepper. Ultrasound-assisted extraction was performed (solvent ratio; 0.7 g/mL, amplitude 80%, for 17 min). The freeze-dried red pepper fruit, coconut oil, and coconut+red pepper oil were characterized by total carotenoids, total capsaicinoids, total phenolic compounds (TPCs), total antioxidant capacity (TAC), fatty acid (FA) profile, and color. It was possible to extract 46.7% of the carotenoids and 42.5% of the capsaicinoids present in the red pepper. However, only about 7% of TCP and TAC were maintained in the coconut+red pepper oil obtained. In the FA profile of red pepper oil, oleic acid and palmitic acid were observed as the main FAs. Conversely, in coconut oil, lauric acid and oleic acid were observed as the main components. In coconut+red pepper oil, the same main FAs were found, but in a lower percentage of lauric acid and higher percentage of oleic acid. Based on the results, coconut oil is a green solvent for the extraction of lipophilic secondary metabolites such as carotenoids and capsaicinoids. These can provide sensory characteristics such as color and flavor to coconut oil from *Capsicum chacoense*. In the oil obtained (coconut+red pepper), a significant difference in the FA profile was also seen, where the majority FA was oleic acid.

**Keywords:** *Acrocomia aculeata* almond oil; capsaicinoids; *Capsicum chacoense*; green solvent; Paraguayan Chaco



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## 1. Introduction

The *Capsicum chacoense*, or “aji del monte”, is a native chili pepper that grows wild, mainly in the Chaco region, Paraguay. It is commonly used as a condiment or vegetable by indigenous peoples. However, its demonstrated content of secondary metabolites such as carotenoids and capsaicinoids makes it attractive for use in products useful for industry [1]. On the other hand, *Acrocomia aculeata*, coco mbokaja, is widely distributed throughout the national territory. Its distribution is so extensive that a large proportion of coconut almonds are currently wasted [2], highlighting the need for studies that demonstrate their utility in different fields, for example, as a green solvent.

In a world increasingly seeking healthy and sustainable food, ecological solvents with biological and renewable bases are being used for the extraction, purification, and formulation of natural and food products [3]. One alternative is vegetable oils, such as those from the Paraguayan coconut almond or mbokaja. The objective of this work was to evaluate the use of coconut almond oil as a green solvent for the extraction of total carotenoids and total capsaicinoids from *Capsicum chacoense* fruit.

## 2. Materials and Methods

### 2.1. Plant Material and Use of the Green Solvent

Raw *Acromia aculeata* almond oil was provided by a private company, then degummed, neutralized, and bleached. *Capsicum chacoense* fruits were manually collected from wild plants in Filadelfia, Boquerón, then lyophilized to a moisture content of less than 10%.

Refined coconut oil was used as a green solvent for extracting carotenoids and capsaicinoids from whole *C. chacoense* fruits. For this, an ultrasonic probe Model Q55 sonicator, (QSonica, Newtown, CT, USA) was used. The probe tip was immersed halfway into the depth level of the refined coconut almond oil mixed with ground chili in the center of the Falcon tube. The solvent ratio was 0.7 g/mL, with an amplitude of 80%, for 17 min at 40 °C. The resulting product was the extract of chili fruits with refined coconut almond oil (CO+PE).

### 2.2. Analytical Methods

The antioxidant potential was determined in the CO, CO+PE, and the lyophilized whole chili fruits. First, an extract was made with methanol (60:40) and acetone (70:30) for the lyophilized fruits, while for the oils, 1 g of oil was dissolved in 3 mL of 80% methanol, then sonicated and centrifuged. This procedure was repeated three times and finally brought to a volume of 10 mL. The total phenolic compounds were analyzed using the Folin–Ciocalteu reagent [4], and total antioxidant capacity by ABTS radical inhibition [5]. Additionally, the concentration of total carotenoids was determined by UV-Vis spectrophotometry [6].

The total capsaicinoids in the lyophilized whole fruit were determined as described Coronel et al. [7]. For the extraction of total capsaicinoids in the oil, 1 g of oil was first dissolved in 3 mL of 80% methanol, then sonicated and centrifuged. This procedure was repeated three times and then brought to a final volume of 10 mL. The obtained extract was injected into the HPLC, maintaining the chromatographic conditions mentioned in [7].

The fatty acid profile of CO, CO+PE, and the oil of the whole *C. chacoense* fruit (PO) extracted cold with hexane in a 3:1 ratio was analyzed. First, fatty acid esterification was performed according to the official AOCS Ce 2-66 method [8] and analyzed in a GC-FID according to the official AOCS Ce 1j-07 method [8].

### 2.3. Statistical Analysis

The results were expressed as means  $\pm$  standard deviation (SD) from three independent replicates. To compare the samples, ANOVA and Tukey's post-test were used. Values with  $p \leq 0.05$  were considered as statistically significant with the assistance of Graph Pad Prism 5.0 software (GraphPad Software, Inc., San Diego, CA, USA) for the calculations.

## 3. Results and Discussion

Table 1 shows the results of TPCs, antioxidant capacity by ABTS radical inhibition, total carotenoids, and total capsaicinoids in CO, CO+PE, and the whole chili fruit. Table 2 shows the fatty acid profile in CO, whole fruit oil, and CO+PE, where it was found that the major fatty acid in the three samples analyzed was oleic acid.

To determine the efficiency of coconut almond oil as a green solvent, the concentration of total carotenoids and total capsaicinoids in CO, whole fruit, and CO+PE was determined. Significant differences were found in the total carotenoid content in the three samples (ANOVA, Tukey's post-test,  $p > 0.05$ ), with the highest value in the lyophilized fruit. It was found that the green solvent extracted 46.7% of the total carotenoids present in the fruit. Higher values of carotenoids have been reported in other hexane extracts of *Capsicum annuum* paprika [9]. However, a study conducted on crushed aji del monte from the Paraguayan Chaco reported a content of up to 239 mg/kg of total carotenoids [7], less than half of that found in the lyophilized fruits of this study ( $515.17 \pm 62.07$  mg/kg) and values similar to those found in CO+PE ( $237.51 \pm 6.07$  mg/kg). The same study reported values of up to 211 mg/100 g of capsaicinoids, lower than those found in this study.

**Table 1.** Antioxidant potential and total capsaicinoids of CO, whole fruit of *C. chacoense*, and CO+PE.

| Parameter                      | CO                       | CO+PE                      | Freeze-Dried Fruits         | Extraction Percentage |
|--------------------------------|--------------------------|----------------------------|-----------------------------|-----------------------|
| TPCs (mg GAE/100 g)            | ND                       | 45.84 ± 0.93 <sup>a</sup>  | 643.40 ± 18.59 <sup>b</sup> | 7.1                   |
| ABTS (mM TEAC/g)               | 0.23 ± 0.06 <sup>a</sup> | 3.03 ± 0.21 <sup>b</sup>   | 39.09 ± 2.01 <sup>c</sup>   | 7.8                   |
| Total carotenoids (mg/kg)      | 6.88 ± 1.55 <sup>a</sup> | 237.51 ± 6.07 <sup>b</sup> | 515.17 ± 62.07 <sup>c</sup> | 46.7                  |
| Total capsaicinoids (mg/100 g) | ND                       | 51.99 ± 2.91 <sup>a</sup>  | 122.42 ± 11.16 <sup>b</sup> | 42.5                  |

ND: not detectable. CO: refined coconut almond oil; CO+PE: chili pepper fruit extract with refined coconut almond oil. TPCs: total phenolic compounds. Results are expressed as mean + SD. GAE: gallic acid equivalents; mM TEAC: millimole equivalents of TROLOX. Different letters in each row indicate significant differences (ANOVA, with Tukey's post hoc test,  $p > 0.05$ ).

**Table 2.** Fatty acid profile of CO, whole fruit, and CO+PE.

|                 | Fatty Acids       | CO                        | Whole Fruit               | CO+PE                     |
|-----------------|-------------------|---------------------------|---------------------------|---------------------------|
| Saturated       | Hexanoic (6:00)   | 0.24 ± 0.07 <sup>a</sup>  | ND                        | 0.21 ± 0.06 <sup>a</sup>  |
|                 | Octanoic (8:00)   | 3.74 ± 0.43 <sup>a</sup>  | ND                        | 5.21 ± 1.71 <sup>a</sup>  |
|                 | Decanoic (10:00)  | 3.47 ± 0.19 <sup>a</sup>  | ND                        | 2.78 ± 0.94 <sup>a</sup>  |
|                 | Lauric (12:00)    | 34.54 ± 1.05 <sup>a</sup> | ND                        | 28.24 ± 3.67 <sup>b</sup> |
|                 | Myristic (14:00)  | 7.87 ± 0.03 <sup>a</sup>  | 0.37 ± 0.01 <sup>b</sup>  | 6.78 ± 0.55 <sup>c</sup>  |
|                 | Palmitic (C16:00) | 7.44 ± 0.18 <sup>a</sup>  | 17.47 ± 0.21 <sup>b</sup> | 7.84 ± 0.56 <sup>a</sup>  |
|                 | Stearic (18:00)   | 2.52 ± 0.03 <sup>a</sup>  | 2.24 ± 0.13 <sup>a</sup>  | 2.04 ± 0.33 <sup>a</sup>  |
| Total           |                   | 59.82                     | 20.08                     | 53.13                     |
| Monounsaturated | Palmitoleic (ω-7) | 1.91 ± 0.06               | ND                        | ND                        |
|                 | Oleic (ω-9)       | 35.52 ± 1.37 <sup>a</sup> | 68.07 ± 0.93 <sup>b</sup> | 40.10 ± 8.53 <sup>a</sup> |
| Total           |                   | 37.43                     | 68.07                     | 40.10                     |
| Polyunsaturated | Linoleic (ω-3)    | 4.69 ± 0.15 <sup>a</sup>  | 5.98 ± 0.23 <sup>a</sup>  | 6.28 ± 0.56 <sup>a</sup>  |
|                 | Arachidonic (ω-6) | ND                        | 3.10 ± 0.35               | ND                        |
| Total           |                   | 4.69                      | 9.08                      | 6.28                      |

ND: not detectable. CO: refined coconut almond oil; CO+PE: chili pepper fruit extract with refined coconut almond oil. Different letters in each row indicate significant differences (ANOVA, with Tukey's post hoc test,  $p > 0.05$ ).

Coconut oil was able to extract 42.5% of the capsaicinoids present in the whole fruit. It was found that TPCs are poorly extracted by coconut oil, which is expected due to the hydrophilic nature of these compounds.

Furthermore, the fatty acid profile of CO, whole fruit oil, and CO+PE was analyzed. Significant differences were found between the three samples (ANOVA, Tukey's post-test,  $p < 0.05$ ) in the myristic acid content, with the highest value for CO ( $7.87 \pm 0.03\%$ ). Overall, it was observed that CO+PE maintains the fatty acid ratio of CO, being the major oil, with a slight decrease in lauric acid and an increase in oleic acid, matching the fatty acid ratio found in the oil of *C. chacoense* fruits. In another study conducted on *Acrocomia aculeata* almond oil cultivated in Brazil, lauric acid (45.25%) and oleic acid (23.96%) were found to be the major fatty acids [10], different from the findings of this study (34% lauric acid and 35% oleic acid). Regarding the oil profile of the red pepper fruit, it was found that the major fatty acid, at 68%, was oleic acid. However, other studies have found that the *Capsicum* genus generally has linolenic acid as the major fatty acid [9,10].

#### 4. Conclusions

This study demonstrates that coconut almond oil is an effective green solvent for extracting bioactive compounds from *Capsicum chacoense*. The oil extracted 46.7% of total carotenoids and 42.5% of total capsaicinoids from the fruit, showing its potential for industrial applications in producing natural antioxidant-rich products. Although less efficient in extracting phenolic content, coconut almond oil maintained the fatty acid profile

of the original samples. These findings highlight the viability of using coconut almond oil as a sustainable and eco-friendly solvent.

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