biology and life sciences forum

Proceeding Paper

Obtaining Integral Kurugua Flour with Antioxidant Potential as Ingredient Foodstuffs †

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† Presented at the IV Conference Ia ValSe-Food CYTED and VII Symposium Chia-Link, La Plata and Jujuy, Argentina, 14–18 November 2022.

Abstract: The aim of the present work was to study the effect of the drying process conditions on the antioxidant properties of the integral fruit of kurugua (*Sicana odorifera* Naud.). The experiments showed that the antioxidant activity of fresh samples of whole kurugua could vary significantly depending on the fruit batch used. The statistical analyses showed no significant differences in antioxidant activity among the drying conditions studied. However, it is important to highlight that the drying process conducted at 80 °C and at an average air speed of 5.8 m/s presented the lowest cost (2.2 USD kW/h), and after 10 h, the raw material reached an aw level of 0.297, which is enough to inhibit the growth of microorganisms. As it is known, a low aw allows for a longer shelf-life of a product and prevents the proliferation of molds and yeasts. There was no significant difference in the concentration of β-carotene between drying times; nevertheless, the resulting flour showed a decrease in luminosity and color variation (b*) with respect to the fresh samples, with a typical browning due to the effects of temperature and air drying. The influence of the drying conditions on the integral kurugua flour is discussed in order to obtain the best dry product. A field of work has opened for future research on the sensory profile and its potential applications.

Keywords: autochthon foods; *Sicana odorifera*; composition; native fruit; nutritional value; flour

Citation: Correa, L.; Gamarra, M.; Sanabria, K.; Coronel, E.; Martínez, M.L.; Calandri, E.; Caballero, S.; Mereles, L. Obtaining Integral Kurugua Flour with Antioxidant Potential as Ingredient Foodstuffs. *Biol. Life Sci. Forum* **2022**, *17*, 22. https://doi.org/10.3390/blsf2022017022

Academic Editors: Norma Sammán, Mabel Cristina Tomás, Loreto Muñoz and Claudia Monika Haros

Published: 10 November 2022

1. Introduction

The *Sicana odorifera* Naud. fruit is considered a source of antioxidants and minerals [1]. However, despite it being a native fruit of Paraguay, its annual crops are underused due to low demand from consumers. The ignorance of its healthy properties limits its application in the diets of regional populations [2]. The kurugua crop was restored less than two decades ago as part of a biodiversity conservation strategy in Paraguay, promoting it as an alternative crop and reintroducing it into the population's food habits. Regionally, the pulps of black and red varieties of kurugua have been studied in relation to proteins, lipids, carbohydrates, and ashes. For the atropurpurea variety, the antioxidant properties of the cascara and its potential use as a source of natural dyes, in particular anthocyanins, have been studied. However, the development of products produced from the whole fruit is scarce, as is the study of its nutritional potential [3]. The aim of this work was to study the effect of the drying process conditions on the antioxidant properties of the integral fruit of kurugua (*Sicana odorifera* Naud.) in order to establish the best drying variable combinations to obtain kurugua flour. The results obtained enable the formulation of foods with a high nutritional quality, produced from the integral kurugua flour, with antioxidant potential.

2. Materials and Methods

2.1. Sampling

The fruits of *Sicana odorifera* were collected in a mature state and without visible damages in the 2021 harvest from a traditional crop by the Cordillera Department, Juan de Mena city (24°57′35.8″ S, 56°44′20.0″ W) Paraguay. Each sample had 20 kg of fruit.

2.2. Processing of the Samples

Once in the laboratory, the fruits were washed and cut into 1 cm-thick slices without separating the seeds and shells. The diameter and thickness were measured with a ruler and weighed in an analytical balance at the AND mark of each sample. A random sampling of 9 kurugua fruits was carried out, with an average of 1600 g of fresh fruit per drying experiment.

2.3. Analytical Methods

For the tray oven assays, the dryer was prepared by adjusting the temperature using a digital controller and the air speed using a manual angle valve, which was measured using the digital anemometer HoldPeak® model HP-866B (Zhuhai, China), according to the condition of the required work. Once the operating parameters were stabilized, the trays were placed inside the equipment, moving them each time a sample was performed, turning the slices by 180°. The operative conditions were performed in duplicate and were as follows: 80 °C—5.3 m/s (Cond. 1); 80 °C—3.8 m/s (Cond. 2); 60 °C—5.3 m/s (Cond. 3); 60 °C—3.8 m/s (Cond. 4).

The drying was performed using a tray-drying oven with forced air by a centrifugal fan and a transversal air inlet. The temperature was controlled by dry and wet bulbs provided at the dryer inlet and outlet. The lineal air speed, the mass flow rate and the relative humidity of the ambient air were controlled.

For the study of the drying conditions and kinetics, a longitudinal experimental design of 2^2 was used. The samples were taken every 60 min in order to determine the humidity, the aw, the total carotenoid content and the color.

For the chemical analysis, the wet content was measured at 45-min intervals for the samples taken from the dryer, and the humidity was analyzed on a RADWAG thermobalance model PM 60.3Y.WH (Torunska, Poland). A total antioxidant capacity (TAC) by an ABTS+ radical cation bleaching assay was carried out on the whole fruit before drying and on the dried product at its equilibrium moisture, in triplicates. For quantitation purposes, a calibration curve was provided with Trolox (aqueous solution 0–500 μM) at 730 nm [4]. The test was carried out spectrophotometrically at 730 nm. The water activity (aw), β-carotene and color were carried out every 2 h using the AOAC 978.19 method on a Rotronic HygroPalm equipment (New York, NY, USA). For the total carotenoid concentration, a spectrophotometric method at 450 nm [5] was employed, using the extraction solution as a blank, and, finally, calculating the concentration of carotene (c) in μg/mL. The color was determined by a standardized method using a ColorStay Colormeter software from Wuite Marten GMBH, 2020 (Baden-Wuttermberg, Germany) at an angle of 45° to the observer. The CIELAB parameters (L*, a* and b*) were selected to inform the color of the samples. All measurements were carried out in triplicate.

The energy cost estimation was calculated from the total drying time of each operational condition, as well as from the current intensities involved in the electrical resistance and the dryer fan. The voltage of the electrical installations was constant and equal to 220 V.

2.4. Statistical Analysis

The data were recorded and processed using the GraphPad Prism 8.2 program (GraphPad Software Inc., San Diego, CA, USA). To determine significant differences, a p value of ≤ 0.05 was considered.

3. Results and Discussion

3.1. Drying Curves

The time required for the fruit slices to reach equilibrium varied depending on the operating conditions. The results obtained from the drying curve under the different operating conditions show that the higher the temperature and air velocity, the lower the time to reach equilibrium humidity (Figure 1).

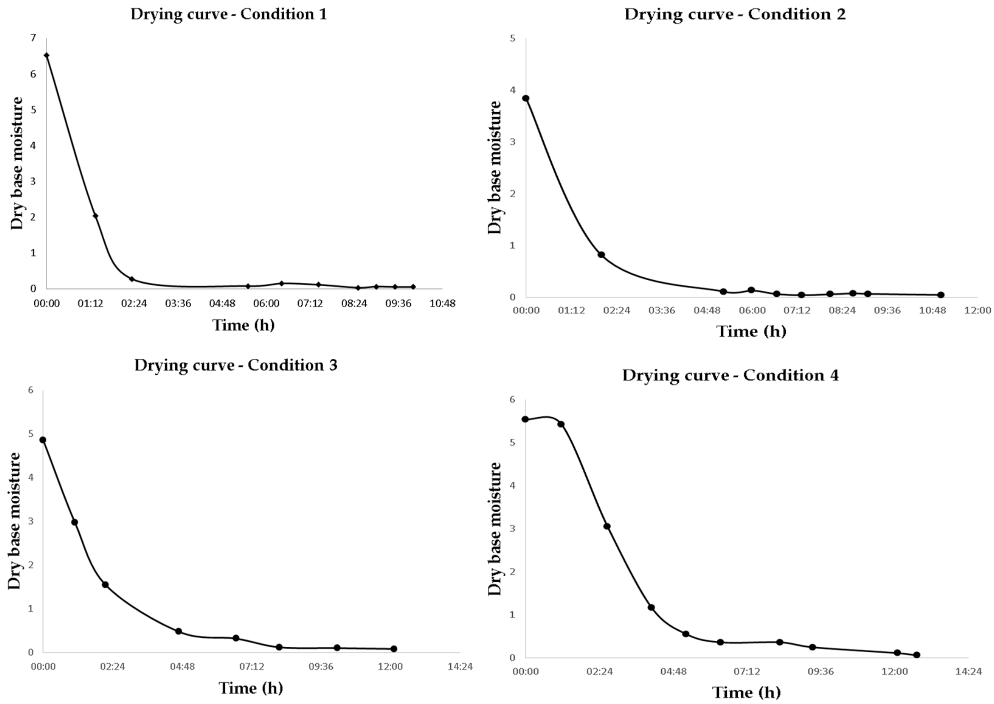

Figure 1. Kurugua fruit drying curves on moisture versus time for four conditions.

3.2. Influence of Temperature and Air Velocity on Total Antioxidant Capacity (TAC)

No significant differences were observed between the TAC values at the different drying conditions. This seems to indicate that the drying speed and the temperature do not affect the TAC of the final product in the evaluated conditions (Figure 2).

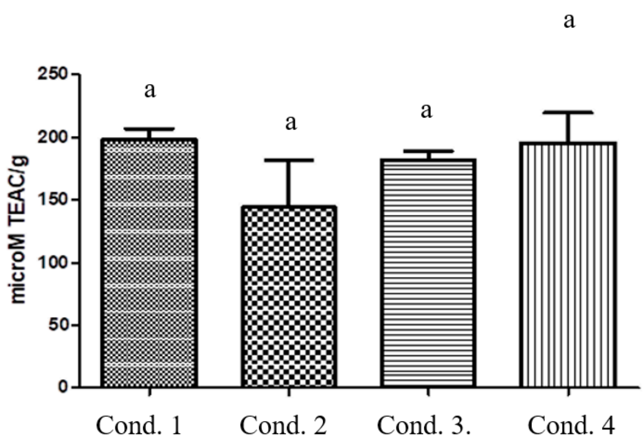

Figure 2. TAC corresponding to kurugua dried fruit flour under different operating conditions. The bars represent the means ± DS (n = 3). The different letters in the bars indicate significant differences between the measurements (single factor ANOVA, Tuckey post-test and $p \leq 0.05$), where Cond. 1 = 80 °C, 5.3 m/s; Cond. 2 = 80 °C, 3.8 m/s; Cond. 3 = 60 °C, 5.3 m/s; Cond. 4 = 60 °C, 3.8 m/s.

The drying times to reach the humidity equilibrium were 9.52 h, 11.2 h, 12.08 h and 12.43 h under Cond. 1 (80 °C, 5.3 m/s), Cond. 2 (80 °C, 3.8 m/s), Cond. 3 (60 °C, 5.3 m/s) and Cond. 4 (60 °C, 3.8 m/s), respectively. As expected, Cond. 1 presented the lowest average drying time and energy cost (2.2 USD kW/h). The aw values showed that 10 h is enough to reach a level of aw (0.297) that inhibits the growth of microorganisms. It is well known that low aw values allow for a longer shelf-life of a product and inhibit the proliferation of molds and yeast [6]. There were no significant differences in the total carotenoid concentrations in the 0–10-h drying range (Figure 3). However, the resulting flour showed a decrease in luminosity and color variation (b*) with respect to the fresh samples, with a typical browning due to the effect of the temperature and air during the drying. In summary, the drying operation conditions to obtain a dry product from kurugua with an acceptable appearance and antioxidant capacity are described. The basis for obtaining a dry product, integral kurugua flour, from experimental drying conditions has been established, and a field of work has been opened for future research on the sensory profile and its potential applications.

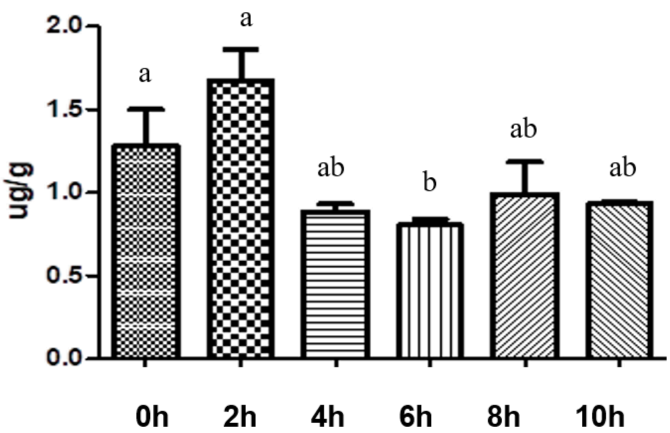

Figure 3. Total carotenoid concentrations at different drying times. The bars represent the means ± DS (n = 3). The different letters in the bars indicate significant differences between the measurements (single factor ANOVA, Tukey test for different comparisons and $p \leq 0.05$).

4. Conclusions

There were no significant variations in the total antioxidant capacity and total carotenoid content between the four drying conditions used in this study. A temperature of 80 °C and an average air speed of 5.8 m/s were chosen due to the low operating cost and adequate aw. Based on these results, future studies can be carried out on the application of this product as a natural ingredient.

Author Contributions: Conceptualization, L.M. and E.C. (Edgardo Calandri); methodology, M.L.M. and L.C.; software, E.C. (Eva Coronel); validation, L.C., M.G. and K.S.; formal analysis, K.S.; investigation, L.C.; resources, S.C.; data curation, L.M.; writing—original draft preparation, L.C.; writing—review and editing, L.M.; visualization, M.L.M.; supervision, L.M., M.L.M. and E.C. (Edgardo Calandri); project administration, S.C.; All authors have read and agreed to the published version of the manuscript.

Funding: This work was supported by the grant Ia ValSe-Food-CYTED (119RT0567), and Blas Imas from the "Kurugua Poty" Foundation.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

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