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Native Fruit Dehydration System With Arduino

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Abstract

Our jungle has many benefits, but during the fruit production season, a high percentage of them are lost due to overproduction. This is why an alternative is proposed to preserve native fruits using the controlled dehydration technique, applying Open Source Arduino, throughout the process. The main objective of this research was to determine what effect the control of temperature and humidity parameters with Arduino has on the dehydration of five native fruits, as well as to know the organoleptic characteristics of five types of dehydrated native fruits and to determine to what extent the enzymatic activity of five types of dehydrated native fruits decreases. The research was carried out using experimental level technology. Since it is a finite population (450 units), the sample size was determined by the formula of (Murray and Larry, 2009), being 149 units, so 30 samples of each type of fruit were taken, making a total of 150 units; applying the Friedman test because they are repetitive measurements. For the evaluation of the organoleptic characteristics, the tasting of 100 students from the Faculty of Systems Engineering and Civil Engineering of the National University of Ucayali was taken into consideration, chosen randomly, not probabilistic; we applied the Likert scale in the form in order to evaluate the opinion of the people. The influence of controlling temperature and humidity parameters with Arduino in the dehydration process of five native fruits has been determined; Both the temperature of 48°C and the humidity of 42% remained constant throughout the dehydration process. In the case that the system sensor detects the temperature that reaches “>= 50°C” it activates the operation of the air extractors and deactivates them if it reaches “<=38°C”. The organoleptic characteristics such as: color,

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shape, smell, texture and flavor do not vary significantly in the analysis of our sample, which had a level of significance ($p<0.05$), confirming our hypothesis. Finally, according to the evaluation of the enzymatic activity we can conclude that: the percentage of humidity decreases significantly, being the Oenocarpus bataua with 2.27% of humidity the lowest and the Myrciaria Dubia with 21.68% the highest, while in acidity: the Myrciaria Dubia with 0.13% is the fruit with the lowest acidity, while the Oenocarpus bataua with 3.6% is the highest, in case of water activity it is minimal with the Oenocarpus bataua with 0.5195 and the highest the Solanum sessiliflorum Dunal with 0.5683.

Introduction

There is a great variety of fruits that are produced in our Ucayali Region, such as Mangifera indica, pineapple, rose apple, among others; which are overabundant during the production season and a good part of these fruits are lost. In the case of the present investigation, the focus was on the results of dehydration processes of five native fruits from the Ucayali region, Peru: Camu Camu (Myrciaria Dubia), Mango (Mangifera indica), Cocona (Solanum sessiliflorum Dunal), Carambola (Averrhoa carambola) and Ungurahui (Oenocarpus bataua). According to the Ministry of Agrarian Development and Irrigation of Peru in the 2020 and 2021, the Ucayali Region has increased its production of Mangifera indica by 45.2% in recent years; This Region is one of the few that has rose apple production. On the other hand, many NGOs, private companies, as well as local governments and the regional government of Ucayali are promoting the planting of products such as pineapple, Mangifera indica, cocoa, banana, among others. There is a shortage when the fruits are not in season, making their prices more expensive because these products are brought from other areas. The purpose of this research was to build an integrated dehydration system for native fruits from the Ucayali Region using Open Source, where we will determine what effect the control of temperature and humidity parameters with Arduino has on its dehydration, as well as its organoleptic characteristics and enzymatic activity. Arduino was used because it is open source, much cheaper, easy to program and easy to purchase parts and pieces. In recent years, the Peruvian University of Applied Sciences conducted the research: "Development of a low-cost fruit dehydration system through temperature control for SMEs", managing to build a system where they integrate a mini PLC for temperature and humidity control; at the National University of Frontera - Peru, the research was developed: "Effect of osmotic dehydration pretreatment on the drying time of melon (Cucumis melo)", where they determined the effect of osmotic dehydration pretreatment on melon slices, While at the National Institute of Agricultural Technology of Colombia they developed a study on "dehydration and drying of fruits, vegetables and mushrooms" managing to obtain information on exact measurements for the dehydration and drying process of fruits, vegetables and mushrooms. Nowadays, the demand for dehydrated fruits is increasing, due to the easy access to them when they are not in season, their intense and exquisite flavor and smell; becoming a trend in healthy and fit foods. There are several methods of fruit dehydration such as: dehydration in a common and solar oven, in a microwave, in the sun, with electric resistors, with forced air and Osmotic Dehydration, in our case we have applied dehydration with electric resistors and forced air, in order to generate the necessary heat and make it constant throughout the dehydration module; controlling the temperature and humidity parameters with Open Source – Arduino.

Materials and Methods

Place and Area of Project Execution

National University of Ucayali

Type and Level of Research

Type

Applied – Technological, For the purposes of determining the type of research, the following was taken as a reference (BARRANTES, R. (2008). Research. A path to knowledge. San José, Costa Rica: Universidad Estatal a Distancia): Because we seek to detail in a certain time the characteristics of the dehydration process applying Open Source to be able to achieve the research objectives.

Level

Experimental, According to (Hernández, Fernández and Baptista, 2010) In the Research Methodology, because: we will obtain data on the dehydration of native fruits through experimentation, we will see aspects of temperature and humidity, we will know the organoleptic characteristics and the enzymatic activity, so that we can compare with constant variables, in order to determine the causes and/or effects of the dehydration of native fruits.

Research Design

Experimental, According to (Palella & Martins, 2014) defines: The experimental design is that according to which we will manipulate the dehydration process of native fruits under strictly controlled conditions of temperature and humidity, so that the process is then described and the organoleptic characteristics and enzymatic activity are known.

For the dehydration process, slices for each fruit have been considered, which will vary the results if they are thicker, so it has been taken into account that they are uniform. Great emphasis has been placed on the safety of handling the fruits in the dehydration process as well as on their transfer for evaluation of the organoleptic characteristics by the students and the enzymatic activity of each fruit in the laboratory of Citeagroindustrial Ut Ambo, Huánuco Region.

Population and Sample

Population

In our case, the population will consist of 5 lots of 90 units of five varieties of native fruits: Camu Camu (Myrciaria Dubia), Mango (Mangifera indica), Cocona (Solanum sessiliflorum Dunal), Carambola(Averrhoa carambola) y Ungurahui(Oenocarpus bataua)

Sample

Since it is a finite population, the sample size was determined by the formula:

$$n_c = \frac{(z_\propto)^2(\mathrm{N})(\mathrm{p})(\mathrm{q})}{i^2(N-1)+(z_\propto)^2(p)(q)}$$

Formula 1: sample calculation

where

- n_c = Number of fruit samples
- N = Population of fruits Myrciaria Dubia (90), Mangifera indica (90), Solanum sessiliflorum Dunal (90), Averrhoa carambola (90) and Oenocarpus bataua (90). making a total of 450 fruit units.
- p = Probability of success, 0.825
- q = Probability of failure, 0.175
- z_α= 0.95 = 1.96 area under the standardized normal curve
- i = Permissible error, 5% or 0.05

Replacing values, a sample size of 149 units was obtained, so we will take 30 samples of each fruit.

The choice of an allowable error of 5% ensures the reliability of the data obtained in the dehydration process.

Likewise, the confidence level of 0.95 means that the confidence interval covers the true value in 95% of the 100% of the dehydration studies.

In the dehydration process developed, it was applied in a controlled manner with the help of the Arduino, controlling the temperature and humidity through the DHT 11 sensor, with a resistor to generate heat if required and a ventilation system to be able to diffuse the heat homogeneously within the dehydration module, it was applied to 30 pieces for each fruit, which were weighed and the humidity was measured at the beginning of the process. For the organoleptic characteristics, a sampling was done with 100 students from the Faculty of Systems Engineering and Civil Engineering of the National University of Ucayali, while the enzymatic activity after the dehydration process was carried out through the Citeagroindustrial Ut Ambo Laboratory, Huánuco Region, for this purpose it was sent to the laboratory: 30 grams of each dehydrated fruit. There have not been control groups, due to the design proposed in the research.

Hypothesis

Controlling humidity and temperature with Arduino significantly influences the dehydration of five native fruits

Specific Hypothesis

- The organoleptic characteristics of five types of dehydrated native fruits do not vary significantly.
- The enzymatic activity decreases significantly in five types of dehydrated native fruits.

Operationalization of Variable

Dehydration Chamber Hardware Design and Electronic Control Interface

Table 1: Operationalization of variable

Variables	Conceptual Definition	Operational Definition	Indicadors	Measurement Scale
Dependent Variable: X: Dehydration system	"Dehydration is one of the oldest ways of processing food. It consists of removing a good part of the moisture from food, so that it does not spoil"	It will be defined through exploratory, controlled tests, to reduce the water content in the fruits, for this the temperature and humidity will be controlled in a controlled environment	• Temperature • Humidity	Nominal
Independent Variable Y: Native Fruits	"Native fruits of Peru have exotic flavors that are very pleasant to the taste. They can be found in different presentations: fresh, processed, in dishes, desserts or liqueurs, or as a complement to a diet rich in vitamins and antioxidants"	The organoleptic properties are determined after the dehydration process	• Color • Shape • Smell • Texture Flavor	Nominal

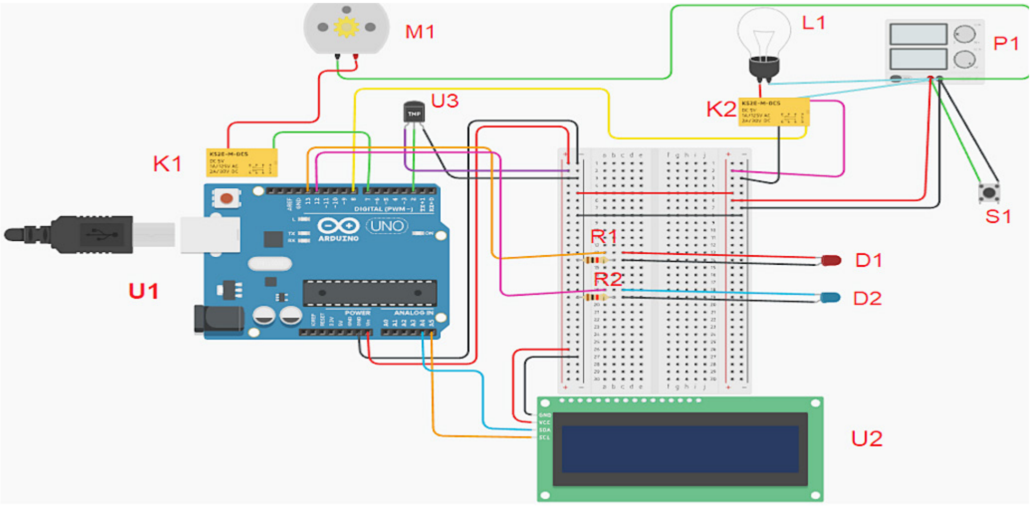

Fig. 1: Dehydration system design

Table 2: Legend, parts and pieces the dehydration system

Name	Quantity	Component
U1	1	Arduino Uno R3
U2	1	LCD 16 x 2 (I2C)
K1 / K2	2	Relay Module, 1CH 5VDC, Allows you to control the on/off of high-power equipment (household appliances).
U3	1	Temperature and humidity Sensor. DHT11; Integrates a capacitive humidity sensor and a thermistor to measure the surrounding air temperature, and displays the data using a digital signal.
P1	1	240w Power Supply, AC/DC 240W 5V 50A WODE, Output efficiency: 78% Terminal block connectors.
L1	1	Ceramic Heat Lamp
S1	1	Power Button
R1 / R2	2	1 kΩ Resistor
D1 / D2	1	Red LED / Blue LES
M1	2	DC Mortor (Fan)

Dimensional Scale Fruit Dehydration Chamber

The methodology used in this research includes the creation of 3D models using design software (TinkerCad), based on the tspecifications of the dehydration chamber to be built. These models that will be presented allow a detailed visualization of the internal structure and the key components of the research.

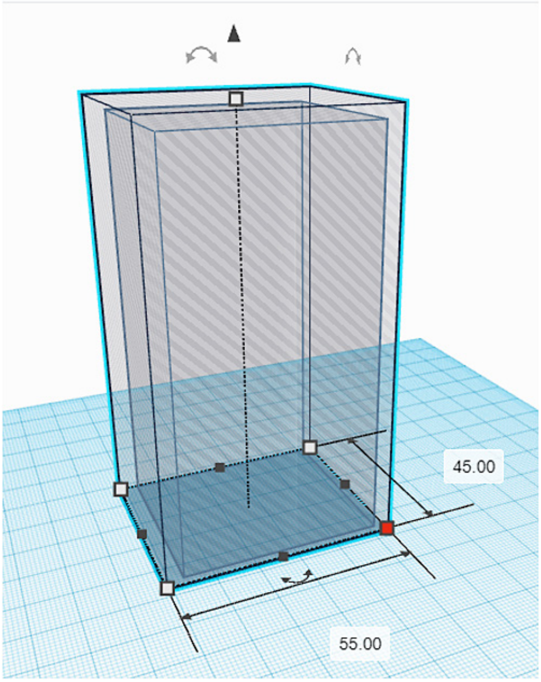

Fig. 2: Dehydration Chamber - Internal Media Front View

Next, the models of the dehydration chamber will be presented on a 1:1 scale.

Dimensional Scale Grill Surgical Steel

Results

Programming the Dehydration System Software

For the development of the dehydration software, we have used the Arduino IDE and the C++ programming language.

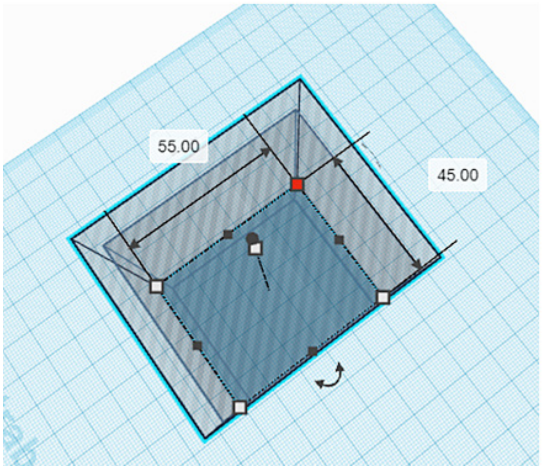

Fig. 2: Dehydration Chamber - Top View

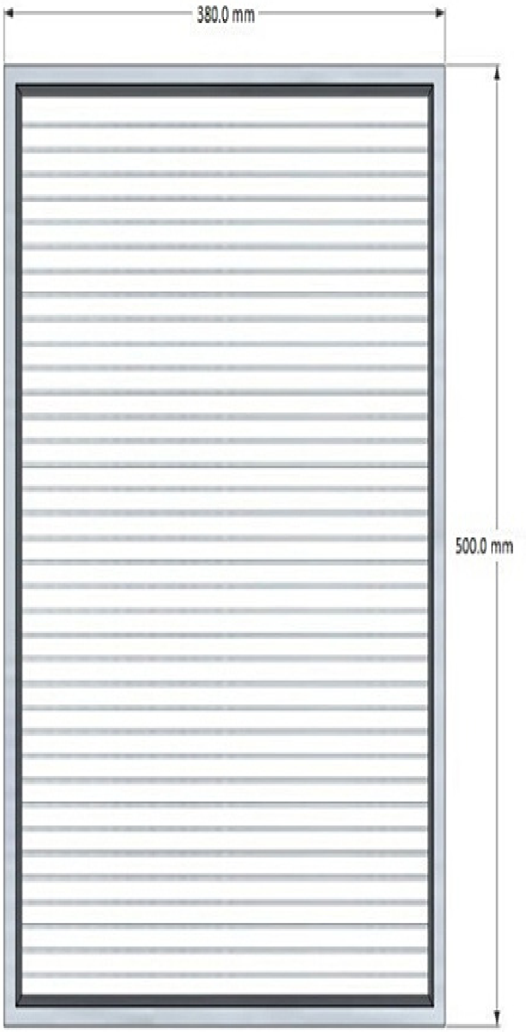

Fig. 4: Top view

Fig. 5: Bottom side view

Partial Interpretation

According to the data obtained in the fruit dehydration process with Arduino, it can be determined that the average Temperature is 48 °C and the Humidity is 42%, they remained more or less constant, which shows that the control generated by the Arduino significantly influences, the variations around the same period of time may be due to the characteristics of each fruit and the start-up of the ventilation extractors that are activated when the temperature reaches the parameter “>=” 50°C and deactivated “<=38°C”.

Determination of the Organoleptic characteristics of Five Types of Dehydrated Native Fruits

To meet this objective, 100 students from the Faculty of Systems Engineering and Civil Engineering were randomly invited to taste the fruits. They were divided into 5 groups of 20 students. Each group was given samples of 5 dehydrated fruits (one dehydrated fruit per group). They were then asked to fill out a form so that they could express the organoleptic characteristics of these dehydrated fruits. A Likert scale was used for evaluation.

Table 3: Data collected for each type of fruit to be dehydrated

fruit	Effective weight in gr.	Total quantity per rack	Total quantity in the 3 racks	Total weight for each rack (g)	Total weight in the 3 racks (g)
Averrhoa carambola	76.10	6	18	456.60	1369.80
Myrciaria Dubia	9.06	18	54	244.62	733.86
Mangifera indica	87.00	6	18	522.00	1566.00
Oenocarpus bataua	5.358	18	54	144.66	433.98
Solanum sessiliflorum Dunal	36.00	6	18	216.00	648.00

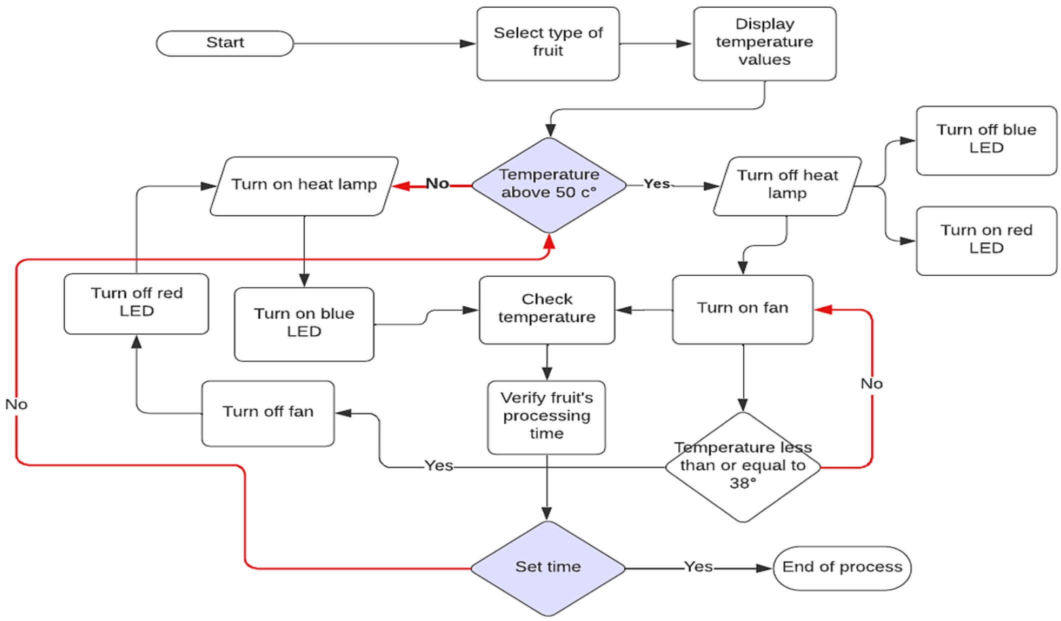

Fig. 6: System Operation Flowchart

Table 4: time of dehydration and average temperature and humidity

Fruit	Time of deshydration (Hours)	Temperature °C	Humidity %
Averrhoa carambola	14	46	40
Myrciaria Dubia	17	48	41
Mangifera indica	7	48	41
Oenocarpus bataua	8	48	42
Solanum sessiliflorum Dunal	1	48	47

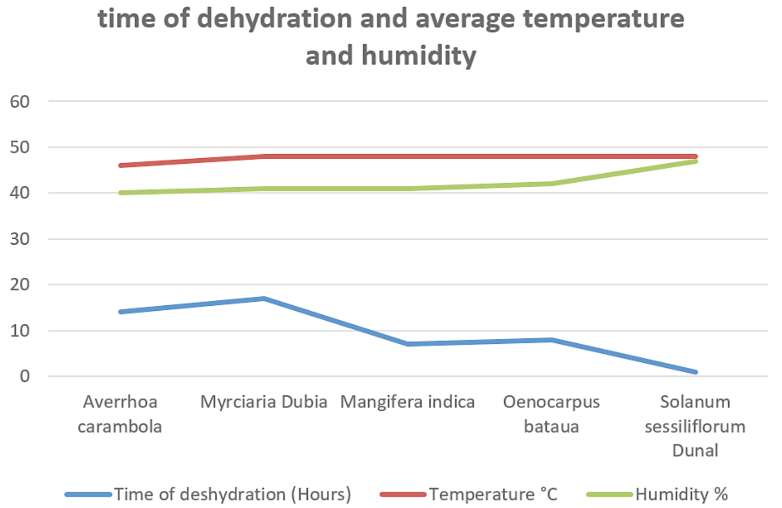

Fig. 7: Temperature / Humidity – fruits

Rating Scale Organoleptic Characteristics: Color, Shape, Smell, Texture, Taste
Excellent (7), Very Good (6), Good (5), Average (4), Bad (3), Very Bad (2), Terrible (1)

Partial Interpretation
we can maintain that: in the case of color, all the fruits have obtained the evaluation of very good, except for the Averrhoa carambola, which on average indicated that after dehydration its color is excellently maintained; in the case of shape, the Oenocarpus bataua has obtained the qualification of good, while the Solanum sessiliflorum Dunal, Myrciaria Dubia and the Mangifera indica the qualification of very good and finally the Averrhoa carambola obtained an evaluation of excellent; in the case of smell, all the fruits obtained a qualification of very good; in the case of texture, the Oenocarpus bataua, the Solanum sessiliflorum Dunal and the Mangifera indica had a qualification of very good, while the Averrhoa carambola and the Myrciaria Dubia obtained an evaluation of excellent; in the case of flavor, all the fruits obtained a qualification of very good, except for the Oenocarpus bataua which obtained a qualification of good.

Table 5: organoleptic characteristics, Average rank

organoleptic characteristics	Average rank				
	Myrciaria Dubia	Mangifera indica	Solanum sessiliflorum Dunal	Averrhoa carambola	Oenocarpus bataua
Color	5	5	5	6	5
Shape	5	5	5	6	4
Smell	5	5	5	5	5
Texture	6	5	5	6	5
Flavor	5	5	5	5	4

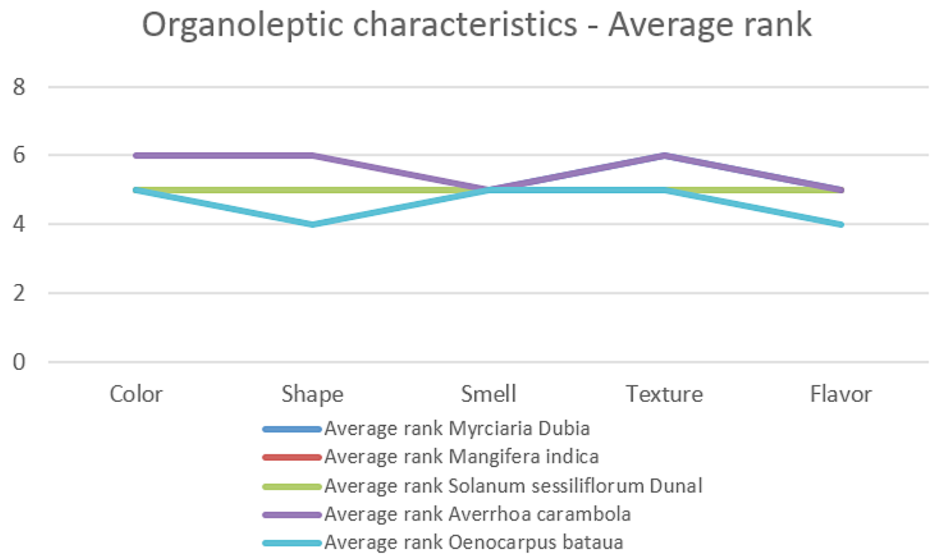

Fig. 8:Organoleptic characteristics of five dehydrated native fruits

Below are the results of the general evaluation, corresponding to the attributes of: color, shape, smell, texture and flavor respectively.

Table 6: Average Range Results

Rank	Average rank
Color	3,46
Shape	2,86
Smell	2,73
Texture	3,65
Flavor	2,32

The statistical results of Friedman's test are also presented:

Table 7: Test Statistics Results

Test statistics[a]	
N	**100**
Chi-square	86,310
Gl	4
asymptotic significance	,000

[a] Friedman test

Partial Interpretation

The analysis performed for the sample, where the significance level Sig.=000 (p<005), then the decision is "Reject the null hypothesis, H0: The organoleptic characteristics do vary significantly" and "Accept the alternative hypothesis Ha: The organoleptic characteristics do not vary significantly".

Table 8: Enzymatic activity of five types of dehydrated native fruits

Fruits	Humidity	Acid	Water Activity
Oenocarpus bataua	2.27	3.6	0.5195
Solanum sessiliflorum Dunal	24.6	2.96	0.5683
Averrhoa carambola	20.56	1.74	0.5328
Myrciaria Dubia	21.68	0.13	0.5374
Mangifera indica	20.98	2.97	0.5431

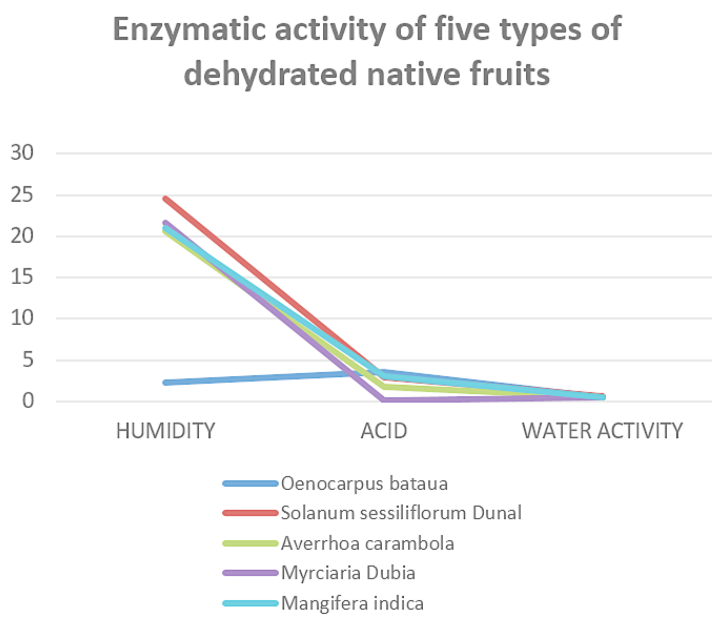

Fig. 9: Enzymatic activity of five types of dehydrated native fruits

Determination of the Enzymatic Activity of Five Types of Dehydrated Native Fruits

In order to determine the enzymatic activity of five types of dehydrated native fruits, the services of the CITEAGROINDUSTRIAL UT AMBO LABORATORY were used, who developed the Humidity and Acidity tests. For this purpose, 30 grams of each dehydrated fruit were sent to the laboratory, obtaining the following results

Partial Interpretation

From the evaluation of the enzymatic activity of five dehydrated native fruits we can conclude that: the percentage of humidity has dropped considerably, with the Oenocarpus bataua fruit having 2.27% humidity with the lowest and the Myrciaria Dubia with 21.68% the highest, while the fruit with lowes acidity is the Myrciaria Dubia with 0.13%, while thefruti with highest acidity is the Oenocarpus bataua with 3.6%, finally the water activity is minimal with the Oenocarpus bataua at 0.5195 and the highest the Solanum sessiliflorum Dunal with 0.5683.

Discussion

In this research, the average temperature for dehydration was 48°C constantly, in the research Effect of osmotic dehydration pretreatment on the drying time of melon (Cucumis melo) of the National University of Frontera was 50°C, while in the National Institute of Agricultural Technology of Colombia, they developed a study on "dehydration and drying of fruits, vegetables and mushrooms" the temperature was 60°C with forced air, finally in the research developed at the Peruvian University of Applied Sciences, entitled "Development of a low-cost fruit dehydration system through temperature control for SMEs," was 48°C.

In all the research related to fruit dehydration, the organoleptic characteristics do not vary significantly. While the enzymatic activity: the percentage of humidity decreases significantly, as does the acidity, as well as the water activity.

Conclusion

- It has been determined that the Arduino control system effectively maintained the dehydration parameters of five native fruits; the average Temperature was 48 °C and the Humidity was 42%, the variations around the same period of time may be due to the start-up of the ventilation extractors that are activated when the temperature reaches the parameter ">=" 50 ° C and deactivated "<= 38 ° C" and the characteristics of each fruit.
- It has been possible to know according to the organoleptic characteristics of: color, shape, smell, texture and flavor are maintained after the dehydration process, carried out for the sample, had a level of significance (p < 005), so we can see the effectiveness of the control with Arduino for the dehydration of the five native fruits analyzed.
- After evaluating the enzymatic activity of five dehydrated native fruits we can conclude that: the percentage of humidity has decreased significantly, having the ungurahui fruit with 2.27% humidity with the lowest and the camu camu with 21.68% the highest, while in considerations of acidity the camu camu with 0.13% acidity is the fruit with the lowest acidity, while the ungurahui with 3.6% is the fruit with the highest acidity, finally the water activity is minimal being the ungurahui with 0.5195 and the highest the cocona with 0.5683.

"Therefore, we can summarize the conclusions that the average dehydration temperature of the native fruits in the research is 48°C and the humidity is 42%; the organoleptic characteristics do not vary significantly at the end of the dehydration process; finally, the enzymatic activity varies significantly as does humidity, acidity and water activity".

Recommendations

- With the results obtained, we can affirm that it is possible to build dehydration systems with a higher capacity in order to take advantage of native fruits according to their season, as well as to take advantage of the conservation of other fruits produced in the Ucayali Region and the country; to disseminate the results of its application in new fruits.
- It is possible to develop an update for a next version that can have predictive elements of the time for dehydration according to the type of fruit and the initial moisture content.
- The final results of the construction of this prototype, being very economical both in

hardware and software by applying an Open Source, makes the application in an industrial model viable.

Acknowledgement

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Conflict of Interest

The authors do not have any conflict of interest.

Data Availability Statement

This statement does not apply to this article.

Ethics Statement

This research did not involve human participants, animal subjects, or any material that requires ethical approval. In this research there are no conflicts of interest. There has been no need to consult with local communities regarding the processing of native fruits, since the national and local governments themselves promote their commercialization and, furthermore, these fruits are abundant in each fruit's season.

Informed Consent Statement

This study did not involve human participants, animal subjects, or any material that requires ethical approval, and therefore, informed consent was not required.

Clinical Trial Registration

This research does not involve any clinical trials.

Permission to Reproduce Material from other Sources

Not applicable.

Author Contributions

- **Freddy Elar Ferrari Fernández:** Conceptualization, Methodology, Writing – Original Draft.
- **Richard Piero Bardales Linares:** Data Collection, Analysis, Writing – Review & Editing.
- **Nilton César Ayra Apac:** Visualization, Supervision, Project Administration.
- **Richard Michel Marín Sevillano:** Funding Acquisition, Resources, Supervision.
- **Giovanni Fredi Tuesta Galán:** performance tests.

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