Revista Boliviana de Química, 2025, Vol. 42, N°2, 39-62
Licenia Celeste Sillerico Quisbert et al.
https://doi.org/10.53287/jgyf9588ny13x

Original article[1]

Bromatological profile of Bolivian Chima flour (*Bactris gasipaes*, Kunt), its use as a partial substitute for wheat flour in bread baking

Licenia Celeste Sillerico Quisbert[1,2], José A. Bravo[1], Leslie Tejeda and J. Mauricio Peñarrieta[1,*]

[1]Instituto de Investigaciones Químicas IIQ-*Alimentos*, Universidad Mayor de San Andrés UMSA, Av. Villazón N° 1995, La Paz, Bolivia; [2]Carrera de Química Industrial, Universidad Mayor de San Andrés UMSA, Av. Villazón N° 1995, La Paz, Bolivia

Keys: *Chima, Palm, Fruit, Flour, Bread, Bromatology, Bactris gasipaes, Peach Palm;* **Claves:** *Chima, Palmera, Fruto, Harina, Pan, Bromatología, Bactris gasipaes, Palmera.*

ABSTRACT

Bactris gasipaes (Chima) is a tropical palm naturally occurring in eastern Bolivia. It is currently exploited principally for its fruits and trunk. This species constitutes dietary part of indigenous populations in the region. We did the analysis of the starch contents of the fruits with scope on the possibility of its utilization as partial flour content together with wheat flour for bread baking. This study included the bromatological profile of the fruit, alimentary product.

RESUMEN

Caracterización bromatológica de la harina de Chima boliviana (Bactris gasipaes, Kunt*), su uso como sustituto parcial de harina de trigo en producción de pan. Bactris gasipaes* (Chima) es una palmera tropical que crece naturalmente en el oriente de Bolivia. Actualmente se explota principalmente por sus frutos y tronco. Esta especie silvestre constituye parte de la dieta de las poblaciones indígenas de la región. Realizamos el análisis del contenido de almidón de los frutos de Chima con miras a la posibilidad de su utilización como contenido parcial de harina junto con la harina de trigo para la panificación. Este estudio incluyó el perfil bromatológico de la fruta, producto alimenticio.

Revista Boliviana de Química, 2025, 42, 39-62
ISSN 0250-5460, Rev. Bol. Quim. *Paper edition*
ISSN 2078-3949, Rev. boliv. quim. *e-edition, May-Nov*
30 noviembre 2025, https://doi.org/10.53287/jgyf9588ny13x

[1]Received July 4, 2025, accepted August 10, 2025, published November 30, 2025. *Mail to: jmpenarrieta1@umsa.bo

INTRODUCTION

Due to lack of knowledge, some tropical fruits are not extensively used in daily food consumption in Bolivia[1]. *Bactris gasipaes* (Chima) is a palm tree native to the tropical forests of the Amazon that reaches 25 m in height and whose fruit has nutritional properties that are more balanced than other tropical fruits. The fruit contains β-carotenes, proteins, phosphorus, calcium, iron and unsaturated and polyunsaturated fatty acids as well as high values in fiber and starch[2]. Palmito is the plant's heart, or the edible inner part of the stem or the palm tree. It is harvested from the inner core and the growing bud of the tree; it can be cooked and eaten directly. It is used in salads and preparations or can be consumed alone[3]. Amazonian fruits can be grown in a sustainable development concept and considered an economic source. Therefore, this research aims to advance in the valorization of Chima fruit flour by obtaining its bromatological profile in view of its use as a partial substitute for wheat flour in baking. The growing demand for composite flours made to reduce wheat in products such as bread, pasta, and cookies that are healthier and more varied leads to studying the effects obtained with a total or partial replacement of wheat bread flour with flours from other cereals, pseudocereals, tubers, and legumes[4]. Mixing flours enriches food by inclusion of dietary fiber and lipids rich in unsaturated fats, on the other hand they contain important levels of micronutrients, vitamins and significant amounts of other bioactive components[5].

Chima

Chima, Bolivian word for *Bactris gasipaes*, is a palm native to the western region of the Amazon basin, naturally occurring in Peru, Bolivia, Brazil, Colombia, Ecuador and Venezuela, but native populations of Chima have been found in Panama and Costa Rica[6]. *Bactris gasipaes* is classified as belonging to angiosperm of Dicotyledonae, Aracaceae family, *Bactris* genus (Fig. 1).

Fig. 1. *Bactris gasipaes* (Bolivian Chima), photos by L. C. Sillerico Quisbert

It is cultivated in small agroforestry systems or in monocultures. Commonly known as peach palm, it receives several other names depending on its geographic origin. It is a long-lived perennial plant that is productive for 50 to 75 years on average. Its population presents an important genetic diversity producing fruits of different colors and qualities. Fruits are edible by humans and very nutritious, after sustained cooking (several hours). The fruits serve as food for birds and other wild animals. Peach palms are also cultivated for the heart of the palm (Palmito), and the trunk can produce valuable wood[7 8 9 10 11 12 13].

Chima fruit, Genetic diversity.

The genetic variety of Chuma fruits include red Chima (Chontaduro), orange and yellow. The red fruit at is green the beginning of fruiting, it presents a flattened shape with less numerous and pronounced grooves than the yellow variety, these being parallel, with an average length of 4.50 cm and width of 3.50 cm.

The yellow Chima is more floury and sweeter than the red fruit, the fruit is top-shaped (it ends in a point), it has an average length of 5.0 cm and a width of 3.50 cm[14] (Fig.2).

Fig. 2. Genetic variety of fruits of *Bactris gasipaes* (Bolivian Chima), anonymous

Chima flour

The blending of different flours is one of the most important properties changing the quality and aesthetic consideration of foods, as it affects the texture, digestibility and end use of starch-based food products. The standardization of the processes for the production of chontaduro flour (Chima) was done, by managing variables such as initial humidity, time and temperature of dehydration, conservation of organoleptic characteristics; in order to obtain flour for human consumption that complies with commercial granulometry parameters and the requirements of regulations. In conclusion, flour is a stable product and must be stored in refrigeration or at room temperature, with a physical barrier composed of packaging that protects it from oxygen, humidity and the external environment; it is susceptible to attack by fungi of the Penicillium genus when storage exceeds the humidity limits[15]. The potential of chontaduro (Chima) as a food source of high nutritional value was demonstrated by studies at the National Academy of Sciences of the United States of America (1975) which stated that it is probably the most balanced fruit of the tropics since it contains proteins, minerals, vitamins, and essential oils. On the other hand, a study by Restrepo and Estupiñan (2007) evaluated the nutritional characteristics of different species of chontaduro (Bactris gassipaes), showing its high nutritional value[16]. The physicochemical properties of the chontaduro epicarp flour obtained by convective drying at 60±2 °C were characterized, giving a concentration of total phenols (23.40±1.30 mg gallic acid/100 g), whose antioxidant activity was evaluated (33.10 %±3.20). Total carotenoids were also determined (59.31±1.61 mg β-carotene/100 g), characterized by color a* (4.95±0.58), color b* (3.25±0.57) and luminosity (33.95±3.16). Additionally, 85% retention of carotenoids and 94% of phenolic compounds was established after 6 months of storage. In conclusion, the flour obtained is a suitable by-product as an alternative agro-food substitute, mainly due to its color attributes and antioxidant activity[17]. Chontaduro from Ecuador was characterized for its nutritional properties and culinary use and advantages over other similar tropical fruits[18]. The Bolivian Chima palm tree was studied for its industrial use for its trunk, or heart of palm. The study is based on the production of preserved hearts of palm packaged in banana vinegar, using stems of the Chima palm tree[13], a member of the Palmaceae family and known worldwide as *Bactris gasipaes*, as raw material. Data was collected from companies in the sector, and the existing supply of palm trees in the geographic sector was determined. The size and location of the heart of palm processing plant located in the city of Riberalta in the department of Beni, Bolivia was used as a reference[19]. The proximate composition of the Peruvian Tijuayo (Chima peruana) was determined to give a percentage of moisture content of 41.5%; ash content of 1.1%; fat content of 6.86%; protein content of 4.94%; fiber content of 1.52%; and carbohydrate content of 44.08%. This project contributes nutrients to the Peruvian diet, making it important to disseminate its nutritional properties and promote its consumption[20]. In this study, we obtained Chima Fruit *(B. gasipaes)* flour through a dehydration and subsequent milling process; the impact of partially replacing wheat flour with Chima flour in breadmaking was evaluated. The process can be summarized as follows:

- Determination of the bromatological profile of Chima flour.
- Qualitative analysis of β-carotene obtained from Chima flour using UV-visible spectra.

- Formulation and evaluation of the effects of replacing wheat flour with Chima flour in baking, using viscoamylography.
- Granulometric analysis of Chima flour.
- Application of Chima flour in mixed wheat flour breads.
- Sensory analysis of Chima bread (organoleptic).

Chima, other features

Other features include Chima as a food[14 21], nutritional values[21 22], β-carotene[21 23], carotenoids, cooking of carotenoids[14 21 23], carotenoids identification (and references therein)[21 24], production of Chima in Bolivia[13 19 21 25], Chima flour composition[21 26].

Varieties of bread in Bolivia; partial replacement of wheat flour by other flours in bread baking,

There are many varieties of bread in Bolivia. They´re made of wheat white flour, or combined with rice, corn, quinoa, oat, cassava, bran, rye, barley, and quinoa flours, as well as other ingredients. Their names vary according to the region: wheat bread is called common bread, battle bread, marraqueta, kauka, cheese bread, sarna; and the mixtures of wheat white flour with integral flour as mestizo bread or chama (chamillo) bread. There is also the Pan de Villa, sliced bread, colisas bread, whole wheat bread, sweet bread, croissants, other bakery products, under those local names, and others.[21 27]

Bread

For bibliographical research on the historical of bread and its composition go for a review by Sillerico et al[21] and some references therein. Structurally this description[21] is exposed as:

2.4 Origin of bread
2.4.1 Varieties of bread in Bolivia
2.4.2 Basic ingredients for baking
2.4.3 Functional characterization of starch
a) Gelatinization temperature
b) Maximum viscosity
c) Brittleness or “Breakdown” as the difference between the maximum viscosity and the viscosity obtained after the constant heating period at 95°C or
d) Retrogradation or “Set back” as the difference between the maximum viscosity and the viscosity at 50°C, expressed in UB or
2.4.4 Chemical composition of wheat flour
2.4.4.1 Starch
2.4.4.2 Humidity
2.4.4.3 Proteins
2.4.4.4 Acidity
2.4.4.5 Sugars
2.4.4.6 Fat
2.4.4.7 Fiber
2.4.4.8 Ashes
2.5 Bread making process
2.5.1 Kneading
2.5.2 Division and weighing
2.5.3 Rounding
2.5.4 Reposing
2.5.5 Formation
2.5.6 Fermentation
a) Fermentation in bread dough
b) Intermediate fermentation
c) Final fermentation or fermentation in pieces
2.5.7 Slicing
2.5.8 Cooking

EXPERIMENTAL AND METHODOLOGY

This research comported three phases: obtaining of Chima flour, bromatological profile, and physicochemical and viscoamylographic analysis of starch behavior.

Plant material

The fruits of Chima palm (*Bactris gasipaes*) were bought in a marketplace in Rurrenabaque (14°26'28.5" S 67°31.669' O, GMS), a small tourist town in the department of Beni, Bolivia, in March 2023. Harvested from the orchard of a resident who sells them at the marketplace, only those in the best condition, without any mechanical or microbiological damage were selected[21].

Raw material

Rinsage and peeling. 3Kg of fresh fruit was rinsed and peeled. The seed was extracted and the fruits' pulp recovered and divided in fine slices.

Dehydration. This process was carried out in a dehydrator at 60°C for 8 h, these are the optimal conditions for obtaining a flour that maintains the smell, color, and flavor characteristics of the original product, even after some of its moisture has been removed.[15]

Milling and sieving. To obtain the flour, the dried pulp was ground in a hand mill and sieved through 30, 35, 40, and 60 µm mesh sizes.

Storage. The flour was stored in sealed plastic bags with a capacity of 500 g until ulterior use. See Fig. 3 for a flowchart of the obtaining of raw material.

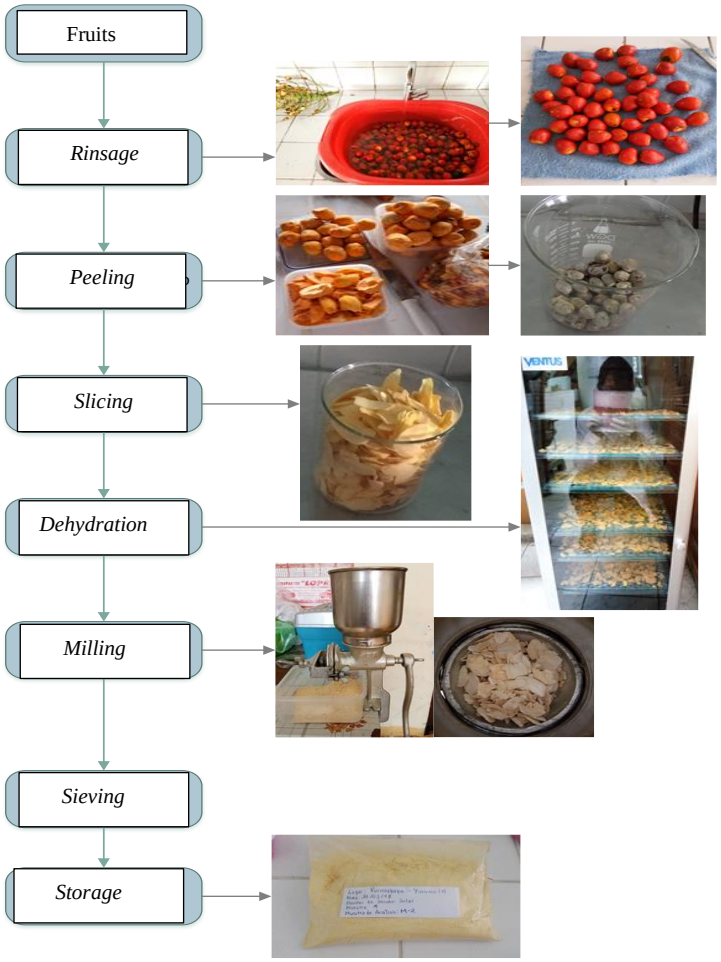


Fig. 3. Flowchart of the obtaining of raw material of Chima fruit flour[21]

Methodology

Physicochemical and bromatological characterization of Chima flour (*Bactris gasipaes*).
The bromatological and physicochemical characterization of Chima flour was carried out including: organoleptic evaluation, moisture, protein, fat content, ash, total sugars, crude fiber and total acidity.

Organoleptic evaluation. See Table 1.

Table 1. Parameters used for organoleptic evaluation, Chima flour

Parameters	Chatacteristics
Taste	Determined by tasting test.
Color	Determined by visual evaluation and classification.
smell	Evaluated by olfactory appreciation.
appearance	Determined by tactile evaluation.

Granulometry of Chima flour
The pre-weighed sieves were placed one on top of the other, then the flour was weighed and transferred to the sieve set, where the flour was sifted under constant agitation for 10 minutes, remaining on each mesh. After this time, the results were recorded, and the percentage retained was calculated.

$$MR = \frac{mr}{m} * 100$$

MR: Mass of flour retained in percentage of mass
m: Mass of the flour sample in g.
mr: Mass of the flour fraction retained on each sieve in g.

Moisture content

1. The sample was heated in 4 previously tared Petri dishes to 105°C, maintaining this temperature until the sample weight was constant. Then, the sample was transferred to the desiccator and weighed as soon as it reached room temperature.

The moisture content in the sample is expressed as a percentage and is obtained according to the following formula:

$$\%H = \frac{G_2 - G_3}{G_2 - G_1} * 100\%$$

%H: Humidity percentage.
G1: Weight of the Petri dish with its lid in g.
G2: Weight of the Petri dish with the wet sample in g.
G3: Weight of the Petri dish with the dry sample in g.

2. IR moisture balance. A 2.5-gram sample was weighed onto an aluminum foil, suitable for the RADWAD moisture balance, model MAC 110/WH, operating at a maximum temperature of 250°C. The flour sample was placed into the moisture balance. The sample was allowed to wait a few minutes, and the moisture content of each sample (Chima flour) was recorded.

Determination of ashes
Approximately 1 g of the prepared sample was placed in the previously tared crucible, and the sample was spread out to ensure a uniform thickness. The sample was pre-calcined in a furnace to prevent ignition. The crucible was then placed in a muffle furnace to incinerate at 550°C ± 20°C until the material was completely burned, including any carbon particles the residue may contain, and white or grayish ash was obtained. The muffle door remained open during calcination. The crucible was then removed with long-arm metal tongs and placed in a desiccator, allowing it to cool to room temperature for 30 minutes. A rapid weighing was immediately performed (to avoid a possible, although not significant, increase in mass due to adsorption of moisture from the environment or air). The ash content, as a percentage of the sample's dry weight, was calculated using the following equation with three decimal places, rounding the mean value to two decimal places:

$$C = 100 * \frac{(G_2 - G_1)}{G(100 - H)} * 100\%$$

C = Ash content in 100 g of dry sample.

G = Sample weight, in grams.
G_1 = Weight of the empty crucible, in grams.
G_2 = Weight of the crucible with ashes, in grams.
H = Percentage moisture content in the sample (before ashing).

Fat content

The cartridge containing the sample was extracted using a Soxhlet system with 75-100 ml (fraction 20-40°C) of petroleum ether in a dried and tared flask. The solvent dripping onto the cartridge was estimated at approximately 150 drops per minute.

The solvent volume was kept constant during the extraction by adding small portions of ether while observing the level in the system flask by eye throughout the process of approximately 4 hours. After the process was completed, the solution was concentrated under reduced pressure. The dry residue in the flask was further dried in an oven at 100°C for 10 minutes, then allowed to cool in a desiccator and weighed. The fat content is expressed as a percentage of the dry sample weight and is calculated using the following equation:

$$Gr = \frac{(G_2 - G_1)}{G} * 100\%$$

Gr = The fat content in percent by weight of dry sample.
G = The weight of the dry sample, in grams.
G_2 = The weight of the flask containing the ether extract, in grams.
G_1 = The weight of the empty flask, in grams.

Protein content

0.1 g of Chima flour was placed in the Kjeldhal flask, followed by 1 g of copper sulfate and potassium sulfate catalysts, and added with 5 ml of concentrated sulfuric acid. The flask was placed in the digester for 4 hours and allowed to cool. 15 ml of the previously prepared 40% sodium hydroxide solution were added. Two layers will form. The flask was connected to the distillation unit, and 50 ml of the distillate containing ammonium was collected in 50 ml of indicator solution and then titrated with the standard hydrochloric acid solution. The percentage of protein was calculated according to:

$$\%Protein = \frac{0.014 * B * V * 100 * F}{m}$$

V = Volume spent on titration (ml)
B = Normality of hydrochloric acid (N)
m = Sample weight (g)
0.014 ; thousand nitrogen equivalents.
F; 6.25 ; Conversion factor (see Table 2).

Lugol's starch test in Chima

The Lugol test was also performed to observe the amylose-iodine complex, as shown in Figure 4.

Figure 4. Chima fruit with positive Lugol's starch test.

Table 2. Protein conversion factors used to convert nitrogen to protein, among different food ingredients.

Food	Conversion factor
CEREALS	-
Wheat, hard, medium, or soft	-
Flour, whole wheat flour	5.83
Flour, medium or low extraction	5.70
Macaroni, spaghetti, wheat pasta	5.70
Bran	6.31
Rice	5.95
Rye	5.83
Barley	5.83
Oats	5.83
OTHER FOODS	6.25

Determination of total sugars.
This reaction results from the formation of polyiodide chains from the reaction of starch with iodine. Amylose, the straight-chain component of starch, forms helices where iodine molecules join together, creating a dark blue to black color.

It was calculated using the following equation:

Total Sugars = Hydrolyzable Sugars + Reducing Sugars

Hydrolyzable sugars
10 g of the sample in 100 ml of distilled water plus 10 ml of concentrated HCl were placed in a 250 ml flask. The solution was then refluxed for 2 hours. After this time, the flask was allowed to cool and neutralized with 40% NaOH, ensuring that the pH was slightly alkaline. The total volume was measured in a 500 ml graduated cylinder, carefully washing the flask to remove all hydrolysate, and filtered. The filtrate was then loaded into a 50 ml burette. In a 500 ml Erlenmeyer flask, 5 ml of Fehling's solution A, 5 ml of B and 100 ml of distilled water were charged, and the solution was brought to a boil. It was titrated against Fehling's reagent until the color changed to green, at which point drops of methylene blue indicator were added and titration continued until the color changed to brick red.
The volume used in the titration is recorded for the calculations, which are expressed in g% of sucrose.
The results were obtained using the following expression:

$$Hydrolyzable\ sugars\% = \frac{Fehling\ factor\ * Total\ Volume}{Sample\ mass * volume\ employed} * 100\%$$

Reducing sugars
5 g of sample was weighed and 150 ml of distilled water was added in a 250 ml graduated cylinder, then drops of 10% lead acetate were added until the proteins completely precipitated, allowing it to settle for two and a half hours in the refrigerator. After that time, add 5 drops of 5% sodium sulfate to precipitate excess lead acetate, the total volume was noted and filtered. The filtrate was placed in a 50 ml burette. 5 ml of Fehling's solution A, 5 ml of B and 100 ml of distilled water were loaded into an Erlenmeyer flask and the solution was brought to a boil. It was titrated when it began to boil until the color changed to green. At that time, drops of methylene blue indicator were added and the titration continued until the color changed to brick red.
The volume used in the titration is recorded for the calculations.
The results were obtained using the following expression:

$$Reducing\ sugars\% = \frac{Fehling\ factor\ * Total\ Volume}{Sample\ mass * volume\ employed} * 100\%$$

Determination of crude fiber

The sample cartridge is prepared (after weighing the filter paper and sample). The cartridge is placed inside the Soxhlet extraction tube, and the apparatus is assembled. 100 ml of petroleum ether is placed in the extraction flask and connected to the extraction tube. The flask is heated in a water bath on an electric hotplate, allowing the solvent to drip from the condenser nozzle to the center of the cartridge at a rate of no less than 150 drops per minute for two to three hours. The volume of solvent is kept constant during the extraction, adding small portions of ether when some of it has evaporated.

The extracted sample is air dried. Once the sample is dry, 1 gram is weighed in a flat-based flask and 200 ml of 0.1275 M sulfuric acid is added. It is heated for one hour, with a circulatory movement so that it does not overflow when it boils. A Buchner funnel is then prepared by placing a previously weighed filter paper to cover the holes in the plate, moisten the filter paper with distilled water and place the solution containing the fiber, allowing the acid solution to drain by suction. Finally, wash with distilled water to ensure that it is free of acid (filtration of the 200 ml volume must be completed within 10 min).

The funnel and its contents are dried in an oven at 130°C ± 3°C for 1 hour. It is removed from the oven, allowed to cool to room temperature in a desiccator, and the filter paper with the sample is weighed as shown in Figure 18.

The crude fiber content is expressed as a percentage of the dry sample and is calculated using the following formula, rounding the results to the first decimal place:

$$F = \frac{G_1}{m} * 100$$

F = Crude fiber content as a percentage of the dry sample weight
G1 = The difference in weight between the filter paper and the treated sample.
m = Weight of the dry sample, in g.

Determination of total acidity

Acidity analysis is a critical parameter that prevents the growth of bacteria, microorganisms, and fungi in food and allows for the determination of the presence of certain mineral acids, organic acids, salts of strong acids, and weak bases. It can be determined in two ways: by 96% neutral alcohol-soluble acidity, due to the presence of free fatty acids related to the degree of preservation of the flour's composition; and by water-soluble acidity (H_2O), due to the presence of acid phosphates, taking into account the degree of extraction present in the flour. There are two methods for titratable acidity analysis:

a) In Water:
Weigh 1 g of sample into a 250 ml Erlenmeyer flask, add 100 ml of distilled water, and stir for half an hour with a magnetic stirrer (to homogenize the sample). Then, let it stand for 30 minutes. Filter the solution, add 3 drops of phenolphthalein, and titrate with 0.1 N sodium hydroxide (standardized) until a faint pink color is obtained.

b) In Alcohol:
100 ml of 95% ethyl alcohol and 3 drops of phenolphthalein, then titrate with 0.1 N sodium hydroxide until a faint pink color. Then, weigh 10 grams of the sample and dissolve it in 100 ml of ethanol in the neutralized solution. Titrate the sample with 0.1 N sodium hydroxide and stir vigorously during the titration, keeping the solution warm.

In both methods the formula is:

$$\boldsymbol{Acidity\%} = \frac{\boldsymbol{ml\ spent\ NaOH\ 0.1\ N * Predominant\ acid\ analysis\ factor}}{\boldsymbol{Sample\ mass}} * \boldsymbol{100}$$

0.0049 expressed as sulfuric acid. Acidity factor for flours in H_2SO_4
0.007 expressed as citric acid.
0.0282 expressed as oleic acid.

Determination of pH

Weigh 10 g of sample into a beaker, add 20 ml of distilled water to a 250 ml Erlenmeyer flask, and top up to 100 ml with distilled water, previously boiled and cooled to 25°C. Stir the mixture until the particles are uniformly suspended. Let stand for 30 minutes and filter into a beaker. Measure the pH with a pH meter.

Determination of the energy value.
According to standard NB 312032, energy value is defined as the gross energy contained in the different inorganic components present in the sample. This gross energy is determined directly by complete combustion in a bomb calorimeter or indirectly by calculation based on the majority of the organic content present in the sample.

The content is expressed in kilocalories per 100 grams of sample, using the following equation:

$$\boldsymbol{VE = (P * f_P) + (EMG * f_{EMG}) + (HC * f_{HC})}$$

VE: Energy Value, in kcal/100g
P: Total Protein, in %
EMG = Fat, in % of mass
HC= Carbohydrate content, in %
f_P=Calorific value for protein = 3.87 kcal/g
$f_{\{EMG\}}$= Calorific value for fat = 8.37 kcal/g
$f_{\{HC\}}$= Calorific value for carbohydrates = 4.12 kcal/g

Carbohydrates
According to standard NB. 312031, carbohydrates are defined as a group of non-nitrogenous organic substances such as starches, dextrins, soluble sugars, some cellulose, pentosans, pectins, gums, and others. Of these, four parameters are added in this practice: moisture, ash, protein, and fat. The difference is taken as carbohydrates.

$$\%HC = 100 - (\%H + \%C + \%P + \%G)$$

% HC = % Carbohydrates
% H = % Moisture
% C = % Ash
% P = % Protein
% G = % Fat (Lipids)

Determination of β-carotene
5 g of the previously ground and homogenized sample was weighed into a 250 ml flat-bottomed flask with a ground-glass lid, then 10 ml of glycerin solution was added and shaken.

50 ml of aldehyde- and peroxide-free alcohol and 10 ml of 30% potassium hydroxide solution were added, and the mixture was refluxed at approximately 40°C for 30 min.

The solution was cooled and transferred to a 250 ml separatory funnel, and the β-carotene was extracted with two consecutive 25 ml portions of petroleum ether. The ether extracts were combined in a second 500 ml separatory funnel and the two portions were washed with 50 ml of water, stirring gently until the aqueous phase turned pink. Drops of the phenolphthalein indicator solution were then added. We filtered the anhydrous sodium sulfate contents through a glass funnel, then transferred them to a 50 ml volumetric flask and topped up the volume with petroleum ether. The absorbance was determined in a spectrophotometer at 450 nm, using petroleum ether as a blank.
A standard for beta-carotene identification was used.
Expression of results:

A = Absorbance
C = Amount of sample in 100 ml

$$\boldsymbol{\beta\ Carotene\ \%\ m/m = \frac{A}{24.4 * C}}$$

UV-Visible Spectrophotometer, (Perking Elmar y Lambda 21); Wavelength: 400 to 800 nm; Bandwidth: 2 nm; Speed: Normal; Data Interval: 1 nm; Peak Table: On; Maximum Graph: 2; Minimum Graph: 1; Tungsten Lamp

Quantitative determination of starch behavior by viscoamylography of Chima flour
A 100 ml distilled water sample was measured using a graduated cylinder, and the moisture content of the flour sample was determined before performing the test. 15 g of the flour sample was placed in the beaker, and the distilled

water was gradually added, stirring constantly until the mixture dissolved (avoiding the formation of lumps) and a homogeneous mixture was obtained. A portion of the water was left in the graduated cylinder.

Once the homogeneous solution was obtained, it was added to the heating cylinder, and the remaining water was rinsed in the flask with the remaining water from the graduated cylinder and then added to the cylinder. The stirrer was inserted into the cylinder, and the heating process began. The initial humidity was controlled, with the respective data for each sample. At the end of the test, the curve and the table of process results were recorded: Torque Units (BU), Temperature (°C), and Time (min). A viscoamylograph Brabender was employed (see Fig. 5)

Figure 5. A viscoamylograph Brabender

Determination of phosphorus content by instrumental method

The total phosphorus quantification method is spectrophotometric, following calcination and acid dissolution of the sample. Spectrophotometric evaluation is based on the formation of the molybdate blue complex, with maximum absorbance at 700 nm wavelength. The preparation of reagents and standard solutions was as follows.

1. **Preparation of reagents and standard solutions**

Standard phosphorus solution

The KH_2PO_4 was dried in a drying oven at 105°C for four hours. 0.4394 g of dry KH_2PO_4, were dissolved, and made up to volume in a 1000 ml = 1 L volumetric flask. This standard solution represents 100 ppm of phosphorus (1 ml = 100 µP).

Ammonium molybdate solution

5 g of ammonium molybdate $(NH_4)_6Mo_7O_{24}•4H_2O$ were dissolved in approximately 50 ml of distilled water, added of the acid solution (15 ml of concentrated sulfuric acid was diluted in 40 ml of distilled water), and made up the mixture to 100 ml with distilled water.

Hydroquinone solution

0.5 g of Hydroquinone were dissolved in 100 ml of distilled water, added a drop of concentrated sulfuric acid, to prevent oxidation.

Sodium sulfite solution

20 g of Na2SO3 were dissolved in distilled water and fill to the mark in a 100 ml volumetric flask.

2. **Calibration curve**

To prepare the calibration curve, the phosphorus concentration range is 0 ppm to 5 ppm. From the 100 ppm P standard solution, a preliminary dilution was made, taking 10 ml with a graduated pipette and placing it in a 100 ml volumetric flask filled with distilled water. The concentration of this solution is 10 ppm phosphorus. The different standard solutions for the calibration curve are prepared from the 10 ppm standard solution, using a 10 ml microburette and

10 ml volumetric flasks or test tubes. All solutions are made with distilled water, and the following reagents were added:
1 ml of ammonium molybdate solution
1 ml of hydroquinone solution
1 ml of sodium sulfite solution
Let the solution stand for 30 minutes to develop the color. Spectrophotometer readings were taken at 700 nm with 1 cm cuvettes. The spectrophotometer was calibrated with the calibration zero (0 ppm P standard solution), and then the standard curve and sample solutions were read. All steps are summarized in the Table 3 .

Table 3. Calibration curve

N	P concentration in ppm	Solution volumen Standard 10 ppm Ml	Reagent Volume mL	Distilled Water Volume mL	Total Volume mL
1	0	0	3	7	10
2	1	1	3	6	10
3	2	2	3	5	10
4	3	3	3	4	10
5	4	4	3	3	10
6	5	5	3	2	10

The data obtained for the concentration and absorbance variables were used to obtain the constants of the linear regression equation.

3. Sample Preparation

0.1 mg of Chima flour was weighed into the porcelain crucible. It was calcined at 550°C in a muffle furnace, taking all necessary precautions until the residue was grayish white. The crucible was cooled in the muffle furnace until the temperature dropped to 200°C, then removed from the furnace to room temperature and placed in a desiccator until cool. The ash in the cooled crucible was added of 5 ml of concentrated hydrochloric acid and then dried on an electric stove, using a fume hood for this process. Another 2 ml of concentrated hydrochloric acid was then added and diluted with deionized distilled water. The solution was then transferred to a 100 ml volumetric flask and made up to the mark with distilled water. For use in the UV-visible spectrophotometer, the solution must be filtered beforehand on filter paper, making a 25/50 dilution. The sample concentrations were determined from the absorbances obtained using the calibration curve constructed with the standard. The data obtained for the concentration and absorbance variables were used to obtain the constants for the linear regression equation.

Determination of Ca, Fe and Mg by atomic absorption AA.

The analysis of the elements present in Chima flour was carried out in the Industrial Chemistry Department UMSA according to of the Bolivian standards NB 312013 and NB 312014.

Air-acetylene flame atomization (2600-2800 °C) was used, with practically negligible analyte ionization; this is appropriate for the effective atomization of a large group of elements. The AA spectrophotometer was Shimadzu AA 7000 with hollow cathode lamps; fed with acetylene/air mixture. Wavelength ranges: 248.33-371.99 nm (Iron); 324.75-327.40 nm (Copper).

Preparation and Formulation of Chima Bread

The bread was made using the following standard formulations of wheat bread with the addition of Chima flour.

M1 = (90% wheat flour and 10% Chima flour).
M2 = (80% wheat flour and 20% Chima flour).
M3 = (70% wheat flour and 30% Chima flour).
M4 = (60% wheat flour and 40% Chima flour).

Ingredients: 1 kg of flour (formulations mentioned above), 150 g of sugar, 25 g of salt, 125 g of yeast, 1.25 g of dough improver, 2 eggs, $1^{1/2}$ L of milk, and 50 g of butter or lard.
The preparation of the dough was initially done by placing the flour on the counter making a hole in the center like a crown. Then, warm milk, butter, egg, yeast and sugar with the help of a spoon were added. Mixing and incorporate all ingredients during knead. Finally, milk with salt dissolved was added. Continuous kneading until getting a smooth

ball that does not stick in hands. Divide and shape the dough on trays to continue with the fermentation, covering with a clean cloth and let it rise for 40 minutes in a warm place until it doubles in volume (trays must be previously greased with vegetable oil or lard so that the dough does not stick to their surface during cooking). See flowchart in Figure 6.

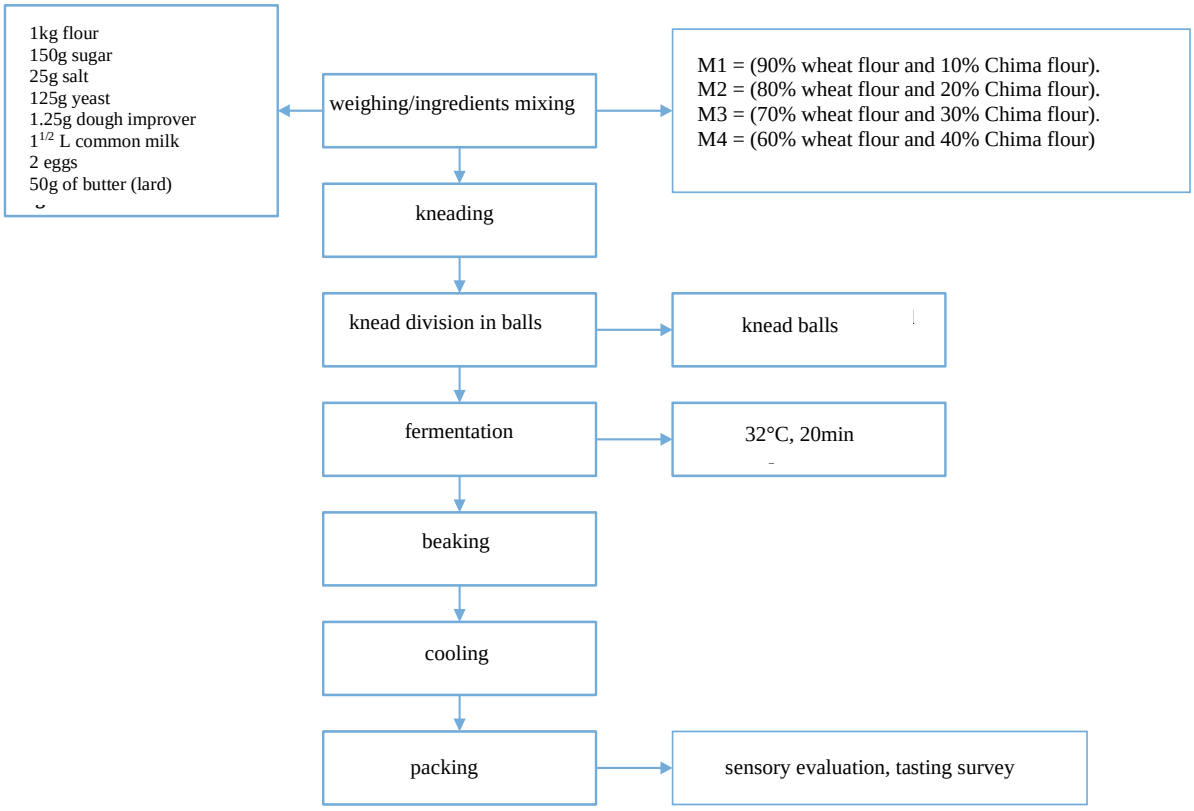


Figure 6. Chima bread preparation

Trays of dough are placed in the oven at 180-200°C for about 25 to 30 minutes (check to see if it's baked). After baking, the bread is allowed to cool to room temperature and then packaged in polyethylene bags and stored for the Chima bread tasting.

Sensory analysis

A sensory analysis was conducted to assess the acceptance of Chima bread and the bread's purchase intention. Each taster was presented with four coded samples. The analysis was conducted in the Pure Sciences Faculty for faculty members and in the Technology Faculty for faculty and students of the Industrial Chemistry program.

The acceptance level was assessed using a 3-point scale (1 = "I like it very much"; 2 = "Indifferent"; 3 = "I dislike it very much"). The tasters evaluated the "appearance" and "color" before consuming each sample, and after tasting it, they evaluated its "texture," "flavor," and overall liking. Finally, regarding purchase intention, the tasters answered a closed-ended question about whether they would buy the product or not. The format of the sensory evaluation for each consumer is shown below:

Table 4. Sensory evaluation of Chima bread

Questions:

1st How much do you like the appearance of Chima bread?
2nd How much do you like the color of this Chima bread?
3rd How much do you like the texture of Chima bread?
4th How much do you like the taste of Chima bread?

Samples	M1	M2	M3	M4
I like it a lot				
I'm indifferent				
I dislike it a lot				

RESULTS AND DISCUSSION

Evaluation of the physicochemical properties of Chima flour and fruit

The processed Chima flour was subjected to organoleptic characterization (see Table 5).

Table 5. Organoleptic characterization of Chima flour and fruit

Parameters	Chima Fruit	Chima flour
Taste	Characteristic of the fruit and floury	Characteristic of the fruit
Color	Orange	Yellow
Odor	Light and pleasant fruity scent, free of foreign odors.	Light and pleasant fruity scent, free of foreign odors.
Aspect	Ovoid and rounded.	Homogeneous flour.

According to Table 5, the flour presented acceptable characteristics, as it was free of foreign matter and met the requirements of Bolivian Standard NB-336004. In this regard, this evaluation serves as a reference to guide laboratory evaluation and the interpretation of results.

Balance of raw material input and output

During the first phase of raw material preparation, 6,500 kg of Chima fruit were collected, consisting of the bunch, peel, mesocarp, and seed.

To obtain Chima flour, the Chima pulp was dehydrated in a 20-tray Ventus Pedestal dehydrator, which was installed in the Industrial Chemistry program.

Because the technical specifications of the equipment were unknown, only a material balance was performed to determine how much dehydrated Chima was obtained during this process. See Table 6

Tabla 6. Possible losses in obtaining Chima Flour

Raw material	Initial mass kg	Final mass kg	% humidity-by-loss	Dehydrated yield in %
Dehydrated Chima				
(sample 1)	3.18	0.77	75.79	24.21
(smaple2)	3.10	0.79	74.52	25.48
Average	3.14	0.78	75.15	24.85

Granulometry

The granulometry process allows to obtain Chima flour in the same size as wheat flour, sieves number 30 (600 microns) and 60 (250 microns) were used to sieve Chima flour. 780g of Chima flr. were sieved in a 600 µm sieve, 18.4g of flr. retained. A second sieving through a 250 µm sieve afforded 761.6g of Chima flr. (0g of flr. retained). See Table 7.

Tabla 7. Granulometry

Sieve (µm)	Applied mass of flour (g)	Mass of flour retained (g) [%]	Mass of flour recovered (g) [%]
600	780.0	18.4 [2.36]	761.6 [97.64]
250	761.6	0 [0]	761.6 [97.64]

The particle size distribution of flour is important since it influences the quality of the texture, appearance, and flavor, as well, the distribution of particle size affects the technological properties and/or baking time of the dough. Large quantities of smaller particles lead to a less extensible and fluid dough[26]. The importance of particle size distribution is related to the diffusion of water within the particles, that is, to the flour's ability to absorb water. Smaller particles absorb proportionally more water, and more quickly, than larger particles, due to their greater surface area for interaction with water molecules.

Bromatological characterization of Chima flour and fruit

The bromatological characterization of Chima flour and the fruit were determined by the Ibnorca (Bolivian Institute of Standardization and Quality) Standards, which establish methods for determining the content of protein, ash, fat, moisture, fiber, etc., in a food analysis laboratory. The results are shown in Tables 8 and 9.

Table 8. Bromatological values of the fruit in each 100 g. Moisture, Protein, Fat, Fiber, Ash, Phosphorus, Calcium, Iron, Magnesium, Energy, Value, Carbohydrates.

PARAMETERS	Fruit (Raw)	References	Bolivian standard
Moisture	44.62±2.26%	49.21 – 36 %	NB – 074
Protein	5.80±0.08%	3.9 - 6.92%	NB - 076
Fat	14.55±1.50%	3.10 – 8.17%	NB - 103
Fiber	46.49±0.83 %	1.3 – 6.25%	NB - 312005
Ash	2.49±0.09 %	1.57 - 2.8%	NB – 664
Phosphorus	1.98±0.02%	33.50 – 55.20 mg	NB – 667
Calcium	563.5±0.02 mg/kg	8.90 – 40.40 mg	NB- 664
Iron	7.85±0.02 mg/kg	0.85 – 2.25 mg	NB- 664
Magnesium	82.2±0.02 mg/ kg	-	NB- 664
Energy value	278.3±0.01 kcal/ g	-	NB – 312032
Carbohydrates	32.54±0.01%	-	NB - 668

In table 10, the proximate composition of the Chima fruit is shown, where humidity is higher and decreases in table 11, the reason explained for this difference in values in the analysis is due to the fact that the Chima fruit was subjected to a dehydration process at a temperature of 60 ° C for a period of 6 hours, proving to be the optimal conditions to reduce the amount of water in the product and extend the shelf life of the fruit, as flour it is indicated that high amounts of water in the flours would facilitate the growth of microorganisms, so Chima flour is complying with the established standard. Chima flour is among the reference values for proteins and ashes, which indicates that factors such as the variety of the fruit, place of production, climatic conditions and the conditions of dehydration of the fruit clearly influence the bromatological characterization of the final product as flour. In studies, high values of protein, fat, humidity, ash, etc. were shown, because their drying process was different with a shorter time at a temperature of 50° C than those from another country and region[26].

Table 11. Bromatological values of Chima flour in each 100 g.

PARAMETERS	Fruit (Raw)	References	Bolivian standard
Moisture	9,06±2.26%	9 - 12 %	NB – 074
Protein	4,85±0.08%	4.05	NB - 076
Fat	13,33±1.50%	13,80 %	NB - 103
Fiber	11.06±0.83 %	4.7 -5.18 %	NB - 312005
Ash	1.14±0.09 %	2.02 %	NB – 664
Phosphorus	1.94±0.02%	49 mg%	NB – 667
Calcium	450.0±0.02 mg/kg	70000ppm	NB- 664
Iron	6.62±0.02 mg/kg	-	NB- 664
Magnesium	78.5±0.02 mg/kg	-	NB- 664
Energy value	425.4±0.01 kcal/g	-	NB – 312032
Carbohydrates	71.62±0.01 %	-	NB - 668

In terms of fiber and fat, they exceed the reference value. According to the literature consulted, this may be due to the peeling process, since the mesocarp contains a higher fiber content. The result is highly beneficial for human consumption, as it contains a high percentage of fiber due to its significant benefits for digestive disorders.

Compared to wheat flour (table 3), Chima flour has higher fat and fiber values. However, although the protein content in Chima flour is lower than that of wheat, Chima flour is rich in energy, carbohydrates, fatty acids, beta carotene, vitamins, and minerals, making it a whole-grain flour with good nutritional qualities for replacing wheat flour.

Regarding mineral content, calcium, magnesium, and iron were analyzed, which are minerals found in small amounts. Although there are variations between the information, it is confirmed that it is an enriched flour.

Total sugars

%Total Sugars=Reducing Sugars+Hydrolyzable Sugars

Chima's fresh fruits

$$\%\text{Total Sugars} = 1.7424 + 22.85 = 24.5924\%$$

Chima's flour

$$\%Total\ sugars = 1.8685 + 17.7220 = 19.5905\%$$

Non-reducing or hydrolyzable sugars (sucrose)

Chima's fresh fruits

$$\%\text{Hydrolyzable sugars} = \frac{0.0565 * 1.42ml}{10.0327 * 3.5ml} * 100\% = 22.85\%$$

Chima's flour

$$\%\text{Hydrolyzable sugars} = \frac{0.0565 * 148ml}{10.0392 * 4.7ml} * 100\% = 17.7220\%$$

Reducing sugars (fructose, glucose, maltose)

$$\%\text{Reducing sugars} = \frac{\text{Fehling factor} * \text{Total volumen}}{\text{Mass of sample} * \text{volume used}} * 100\%$$

Chima's fresh fruits

$$\%\text{Reducing sugars} = \frac{0.0565 * 150ml}{10.0284 * 48.5\ ml} * 100\% = 1.7424\%$$

Chima's flour

$$\%\text{Reducing sugars} = \frac{0.0565 * 150ml}{10.0124 * 45.3\ ml} * 100\% = 1.8685\%$$

These results show that in the present study the percentage of hydrolyzable and reducing sugars is high; this is because the content of hydrolyzable sugars is strongly influenced by variety, altitude, and temperature; at higher altitudes, atmospheric temperatures are lower, therefore, the content of reducing sugars increases.

Determination of total acidity using conventional methods

Chemical method, by titration; using alkalimetry as the dosage technique.
0.007 expressed as citric acid.
0.0282 expressed as oleic acid.
0.0049 expressed as sulfuric acid.

In water:
Chima's fresh fruits and chima´s flour

$$\text{Acidity\%} = \frac{\text{ml NaOH 0.1 N} * \text{Predominant acid factor (citric or oleic or sulfuric)}}{\text{sample mass}} * \mathbf{100}$$

Predominant acid factor	Chima´s fresh fruit				
	ml	Concentration	Acid factor	Sample mass (g)	Acidity %
Sulfuric acid	0.5	0.102	0.0049	1.0816	0.0231
Citric acid	0.5	0.102	0.007	1.0816	0.0330
Oleic acid	0.5	0.102	0.0282	1.0816	0.1330

Predominant acid factor	Chima´s flour				
	ml	Concentration	Acid factor	Sample mass (g)	Acidity %
Sulfuric acid	0.9	0.102	0.0049	1.0202	0.0441
Citric acid	0.7	0.102	0.007	1.0202	0.0490
Oleic acid	0.9	0.102	0.0282	1.0202	0.2538

The presence of sulfuric, citric and oleic acids in the Chima fruit is within the quality parameters. Oleic, citric and sulfuric acids, if lower than 0.22%, can modify the quality of the gluten, decreasing its elasticity and hydration level, and increasing the acidity with storage time. The acidity of foods is due to the organic acids present in their composition; their determination is performed by acid-base titration, usually with a standardized sodium hydroxide solution. Therefore, acidity is expressed in terms of the predominant acid.

Acidity analysis is an extremely important parameter as it prevents the proliferation of bacteria, microorganisms, and fungi in food. It allows the determination of certain mineral acids, organic acids, salts of strong acids, and weak bases.

The Chima flour analyzed shows acceptable acidity values of 0.0441; 0.0490; and 0.2538%, meaning it is within acceptable consumption parameters.

In alcohol:
Chima's fresh fruits and chima´s flour

$$\text{Acidity\%} = \frac{\text{ml NaOH 0.1 N} * \text{Predominant acid factor (citric or oleic or sulfuric)}}{\text{sample mass}} * \mathbf{100}$$

Predominant acid factor	Chima´s fresh fruit				
	ml	Concentration	Acid factor	Sample mass (g)	Acidity %
Sulfuric acid	1.2	0.102	0.0049	9.9735	0.0060
Citric acid	1.2	0.102	0.007	9.9735	0.0086
Oleic acid	1.2	0.102	0.0282	9.9735	0.0346

Predominant acid factor	Chima´s flour				
	ml	Concentration	Acid factor	Sample mass (g)	Acidity %
Sulfuric acid	0.95	0.102	0.0049	9.772	0.0049
Citric acid	0.98	0.102	0.007	9.772	0.0072
Oleic acid	10.1	0.102	0.0282	9.772	0.2973

Chima flour showed acceptable acidity values of 0.0049, 0.0072, and 0.2973%, within acceptable consumption parameters. Oleic, citric, and sulfuric acids, if higher than 0.22%, can alter gluten quality by decreasing its elasticity and hydration, while acidity increases with storage.

Determination of the pH of Chima

Table 12, shows pH of fresh fruits of Chima to be within the parameters of the theoretical value 6.5 - 7 pH[15]. Chima flour manifested slightly acidic. This pH favors the conservation of flour, since having a neutral or alkaline pH, facilitates the proliferation of microbes produced by molds and yeasts, as well as the rancidity process of fats can accelerate.

Table 12. Bromatological values of Chima flour and Chima fresh fruits per 100 g

	Chima flour	**Chima fresh fruits**
pH	5.74 -5.69	6.13 - 6.14
Conductivity	1677 µs/cm	1207 µs/cm
Temperature	14.19 ºc	14.19 ºc

Identification of *β*-carotene; Bolivian Standard NB 39027

The presence of *β*-carotene was detected by its UV spectrum with a maximal absorbance of 1.584 at λ 454 nm. This value is similar to that reported in the literature[28]. To identify whether the β carotene molecule is present in our extract, a stock solution of known concentration C=0.1 ppm was prepared.

$\boldsymbol{\beta - Carotene}$ % $\mathbf{m/m} = \frac{\mathbf{A}}{\mathbf{24.4 * C}}$; A: absorbance, C: sample mass (*c*0.1); $\boldsymbol{\beta - Carotene}$ % $\mathbf{m/m = 0.649}$ %

The presence *β*-carotene gives a mild orange color to Chima flour.

Determination of phosphorus concentration (P-conc.); instrumental method

Phosphorus in Chima fruit and flour was determined by UV-Visible spectrometry.

After establishment of the calibration curves by linear regression by means of y = 0,1213x - 0,0016 R^2 = 0,9998. Calculation of the concentration of phosphorus in Chima fruits and flour was done by the equation:

$$Y_{abs} = A + B * X_{P-conc}$$

$$Y_{abs} = -0.0016 + 0.1213 * X_{P-conc}$$

$$X_{P-conc} = \frac{Y_{abs}-(-0.0016)}{0.1213} \quad (1)$$

After calculations, the mean value of the absorbance of the Chima fruit and Chima flour were 0.060 and 0.059 respectively. These values were applied in equation (1) above, the results are:

Fresh fruit

$$X_{P-conc} = \frac{0.060 - (-0.0016)}{0.1213} = 0.508 \text{ mg/L}$$

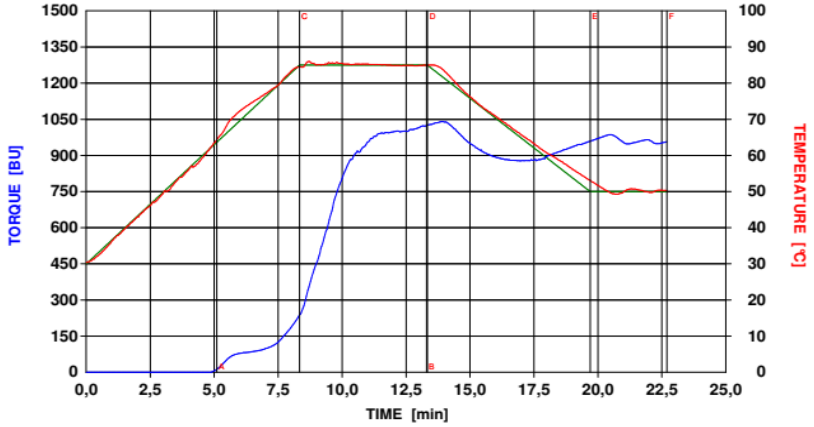
Flour

$$X_{P-conc} = \frac{0.059 - (-0.0016)}{0.1213} = 0.500 \text{ mg/L}$$

Quantitative determination of starch behavior by Viscoamylography of Chima flour

Measurements of the rheological characteristics of the Chima flour used are of utmost importance. In this case, they are evaluated using a viscoamylograph, which is a device that allows continuous graphic recording of variations in the viscosity of flour suspensions in water as the temperature is uniformly increased. Figures 7, 8, 9, and 10 show the different substitutions that were made. The increase in viscosity is noted as being due to the gelatinization of the starch, although the amylase enzymes in the flour also affect the viscosity. The viscosity of a starch gel is affected by the action of alpha-amylase, which disintegrates the starch gel during heating of the suspension.

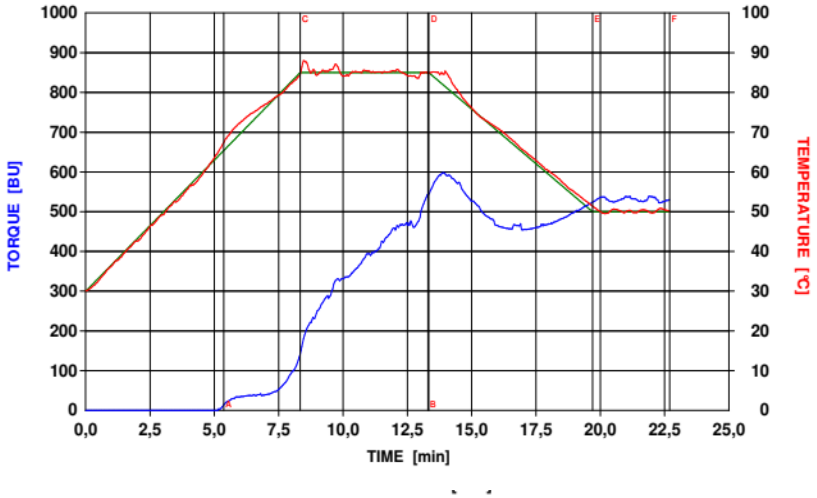
On the other hand, the viscoamyogram provides information on the damage suffered by starch during the drastic milling process. The Brabender amylograph continuously measures the agitation resistance of a flour-in-water suspension while the temperature is raised at a constant rate of 1.5°C/min from 90°C to 95°C and then maintained at a constant temperature of 95°C. The amylogram with the degree of gelatinization is recorded in the meantime.



Evaluation

Point	Name	Time [HH:MM:SS]	Torque [BU]	Temperature [°C]
A	Beginning of gelatinization	00:05:06	12	64,4
B	Maximum viscosity	00:13:18	1024	85,0
C	Start of holding period	00:08:20	237	84,5
D	Start of cooling period	00:13:20	1026	84,9
E	End of cooling period	00:19:42	959	53,1
F	End of final holding period	00:22:42	957	50,2
B-D	Breakdown		-2	
E-D	Setback		-67	

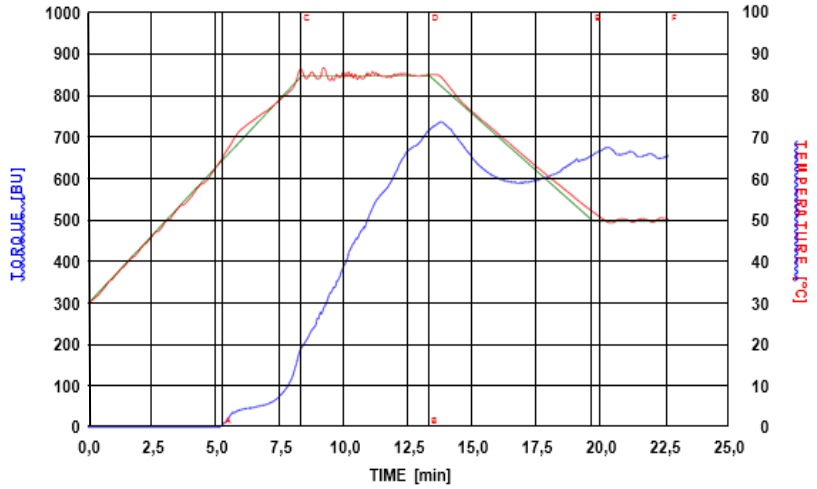
Figure 7. M1 = (90 % wheat flour and 10 % Chima flour).



Evaluation

Point	Name	Time [HH:MM:SS]	Torque [BU]	Temperature [°C]
A	Beginning of gelatinization	00:05:22	14	67,4
B	Maximum viscosity	00:13:18	543	85,1
C	Start of holding period	00:08:20	141	84,5
D	Start of cooling period	00:13:20	544	85,0
E	End of cooling period	00:19:42	524	51,4
F	End of final holding period	00:22:42	530	50,1
B-D	Breakdown		-1	
E-D	Setback		-20	

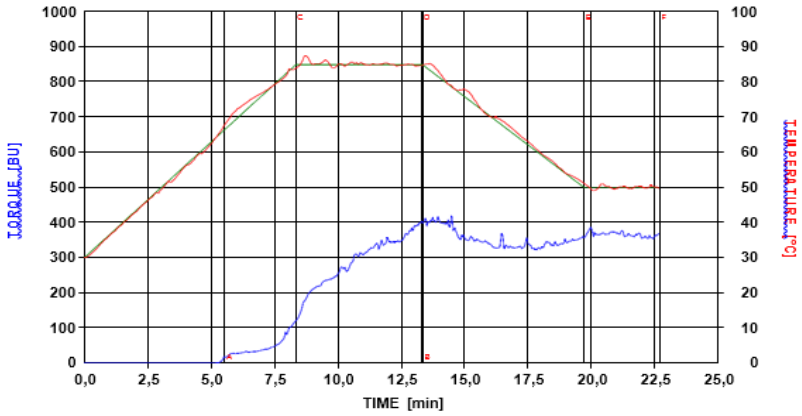
Figure 8. M1 = (80 % wheat flour and 20 % Chima flour).



Evaluation

Point	Name	Time [HH:MM		To rq	Temper ature
A	Beginning of gelatinization	00:05:18		12	6
B	Maximum viscosity	00:13:18		71	85,3
C	Start of holding period	00:08:20		19	8
D	Start of cooling period	00:13:20		7	8
E	End of cooling period	00:19:42		6	5
F	End of final holding period	00:22:42		65	50,2
B	Breakdown			-1	
E	Setback			-	

Figure 9. M1 = (70 % wheat flour and 30 % Chima flour).



Evaluation

Point	Name	Time [HH:MM:SS]	Torque [BU]	Temperature [°C]
A	Beginning of gelatinization	00:05:30	17	67,5
B	Maximum viscosity	00:13:18	405	84,7
C	Start of holding period	00:08:20	121	84,0
D	Start of cooling period	00:13:20	399	84,8
E	End of cooling period	00:19:42	359	51,2
F	End of final holding period	00:22:42	362	49,7
B-D	Breakdown		6	
E-D	Setback		-40	

Figure 10. M1 = (60 % wheat flour and 40 % Chima flour).

An important characteristic is the viscosity of the product after gelation and for adjusting the addition of malt to the bread flours. The height of the curve is obtained from the viscoamylograph, which indicates the degree of gelatinization. A low curve indicates poor gelatinization, meaning that the starch does not bind with water and remains free, as can be seen in Figure 10. The bread crust would be moist and gummy.

A high curve indicates a high degree of gelatinization and a good ability to retain water, so that it does not remain free, as can be seen in Figure 9. The result will be bread with a dry crust on the palate. The most suitable type of flour will give an intermediate curve, as can be seen in Figures 7 and 8, resulting in bread with a semi-moist crust.

Formulation of Chima bread

A standard wheat bread formulation was followed for the bread making process, including Chima flour. The ingredients used were a flour mix, sugar, butter, eggs, and yeast.

Four different bread formulation treatments were used.

M1 = (90% wheat flour and 10% Chima flour).

M2 = (80% wheat flour and 20% Chima flour).

M3 = (70% wheat flour and 30% Chima flour).

M4 = (60% wheat flour and 40% Chima flour).

The Chima bread formulation consisted of 5 kg of flour (formulations mentioned above), 300 g of sugar, 50 g of salt, 250 g of yeast, 2.5 g of dough improver, 3 liters of milk, and 100 g of butter. See Fig. 6.

The bread product formulation and production process were standardized and optimized, taking into account physical and chemical variables such as temperature, humidity, time, and dough mixing. The improved bread was made with four trials using different proportions of flours, keeping the complementary ingredients constant to better determine the bread dough, taking into account characteristics such as homogeneity, stickiness, bread volume, and others.
To optimize the final bread product, the best mix combination is chosen with different attributes such as: percentages of flour blends, culinary characteristics of the flours in the product of the best bread chosen, and organoleptic or sensory characteristics of the product.

The formulation for making Chima bread followed the aforementioned formulation, on which all bread formulations are based, with various substitutions.

Sensory evaluation of Chima bread

The questions are:

1. How much do you like the appearance of Chima bread? As we could see, the 10% Chima bread looks better, followed by the 20%, 30%, and 40%, which are visible to the eye.
2. How much do you like the color of Chima bread? Chima's 30% bread has a better color and people like it, followed by the 20%, 10%, and 40% which look very orange, as if they were a cookie.
3. How much do you like the texture of Chima bread? Chima's 10% bread has a better appearance and soft texture that differentiates it from the others, 20% (a little hard), 30% (semi-hard) and 40% hard like a biscuit that can be appreciated by touch and tasting.
4. How much do you like the taste of Chima bread? Chima bread at 10% is better in flavor, being appetizing and different from other breads, then there is 20% which is also pleasing to the palate, 30% is a little sour, then 40%.
5. How much do you like this product overall? Chima bread at 10% in appearance, texture and flavor being appetizing and different from other breads, then there is 20% which also pleases the palate being acceptable and the 30% to 40% is a little sour.
6. Would you buy this product? More than 80% of Chima bread would buy it because it is a whole wheat bread with a pleasant and appetizing flavor, because it is healthy and different from other breads that one frequently buys.

Conclusions

Chima flour was obtained through a dehydration process for use in breadmaking. The results show that up to 10% Chima flour can be included in many local breads, improving its nutritional value.

The bromatological analysis showed that Chima flour has a higher content of fat, vitamins, minerals, amino acids, and fiber compared to wheat flour, which is favorable for replacing partially, wheat flour in the production of baked goods. This is despite the decrease in the bread's protein content due to the partial replacement of Chima flour.
It was identified that Chima flour contains β-carotenes, pigments that contribute to the red and orange color of Chima fruit and flour. The organoleptic and bromatological properties found for both the fruit and Chima flour are within established parameters.

The particle size distribution of Chima flour is an important aspect of our bakery production, as proper particle distribution allowed for greater uniformity in the finished product, which was evident when kneading the dough and baking the bread.

To determine the optimal proportion of wheat flour and Chima flour, viscoamylographic tests were performed. These tests helped us understand the dough's behavior in different proportions, such as 60/40, 70/30, 80/20, and 90/10. Figure 33 shows an intermediate curve, with a higher degree of gelatinization and good water retention capacity. The best partial substitution of wheat flour/partial Chima flour is 10%.

The 10% substitution level of Chima flour in the partial replacement of breads was favorable in terms of sensory acceptance, flavor attributes, aroma and texture parameters, however higher substitution levels such as 30 and 40% of Chima flour, caused changes in the texture and sensory parameters in the breads, reflecting the effect of Chima flour.

This research contributes to the revalorization of Bolivian foods, particularly Amazonian species like *Bactris gasipaes*, which hold high potential as nutritious and sustainable alternatives for food innovation and local economic development.

REFERENCES

[1] F. Lino and V. Padilla, *Apthapi, Revista de la Carrera de Ingeniería Agronómica, Universidad Mayor de San Andrés*, 2016, **2**, 26.
[2] S. Dussán-Sarria**,** D. L. Hurtado-Hurtado and J. H. Camacho-Tamayo, *Información Tecnológica*, 2019, **30**, 3.

[3] L. M. Guiza Parra and L. Y. Herrera Suárez. **2012**, Factibilidad para la creación de una empresa productora de cogollos de palma de Chontaduro (pejibaye, Bactris gasipaes) en el municipio de San Alberto, Cesar (BSc thesis), Universidad Industrial de Santander-INSED, retrieved from content.
[4] R. O. Díaz S. and M. S. Hernández G., *Vitae*, 2012, **19**, S270.
[5] L. Alvarez-Jubete, E. K. Arendt and E. Gallagher, *Trends in Food Science & Technology*, 2010, **21**, 106.
[6] S. Graefe, *Biodiversity and Conservation*, 2013, **22**, 269.
[7] M. C. Araújo, D. P. Rodrigues, S. Astolfi Filho and C. R. Clement, *Crop Breeding and Applied Biotechnology*, 2010, **10**, 211.
[8] C. R. Clement, R. P. Santos, S. J. M. Desmouliere, E. J. L. Ferreira and J. T. Farias Neto, *PLoS one*, 2009, **4**, e4564
[9] C. R. Clement, *Agroforest Syst*, 1988, **7**, 201.
[10] A. Ares, N. Falcao, K. Yuyama, R. S. Yost and C. R. Clement, *Nutr Cycl Agroecosyst*, 2003, **6**, 221.
[11] C. R. Clement, 'Pejibaye: Frutas de origen tropical y subtropical', ed. by S. Nagy, P. E. Shaw and W. F. Wardowski, Florida Science Source Inc., Lake Alfred, 1990, pp. 302-332.
[12] N. González-Jaramillo, N. Bailón-Moscoso, R. Duarte-Casar and J. C. Romero-Benavides, *Plantas*, 2022. **11**, 3134.
[13] V. Vargas Escobar and M. Moraes, 'La Chima: Palmeras en Tumupasa en La Paz, Bolivia', ed. by M. Moraes, Team Graphics SRL, La Paz, Bolivia, 2014, pp. 36-42.
[14] M. A: Córdova Palomino and W. J. Terán Verzola, 2014, Aprovechamiento del mesocarpio del chontaduro (Bactris gasipaes H.B.K) para elaboración de harina, bebida y yogurt (BSc tesis), Universidad de Guataquil, Guayaquil, Ecuador.
[15] S. P. Godoy, E. Motta, C. Forero, D. Diaz and G. Luna, *Biotecnología en el Sector Agropecuario y Agroindustrial*, 2006, **4**, 105.
[16] J. Restrepo and J. A. Estupiñan, https://hdl.handle.net/10893/8869
[17] J. Martínez-Girón, X. Rodríguez-Rodríguez, L. X. Pinzón-Zárate and L. E. Ordóñez-Santos, *Corpoica Cienc Tecnol Agropecuaria*, 2017, **18**, 599.
[18] G. Tamayo Ortega, 2010, Estudio investigative del chontaduro, análisis de sus propiedades, explotación y aplicación creativa, en el ámbito culinario (BSc thesis), Universidad Tecnológica Equinoccial, Quito, Ecuador, retrieved from https://www.yumpu.com/es/document/read/14497725/estudio-investigativo-del-chontaduro-analisis-de-sus-propiedades-
[19] Y. G. Tirina Cartagena, 2018, Producción de conserva de palmito envasado en vinagre de banano (BSc thesis), Universidad Mayor de San Andrés, La Paz, Bolivia, retrieved from http://repositorio.umsa.bo/xmlui/handle/123456789/20786
S. S. Kupfer and J. Bana, *Gastrointestinal Endoscopy Clinics of North America*, 2012, **22**, 639.
[20] R. M. León Ávalos, **2015**, Caracterización proximal del Tijuayo, *Bactris gasipaes* H.B.K., cáscara rojiza procedente de la region de San Martín (BSc thesis), Universidad Nacional de Trujillo, Trujillo, Perú, retrieved from https://dspace.unitru.edu.pe/items/ea94f8bf-6b65-4a27-9ea9-ce40d452e16b
[21] L. C. Sillerico Quisberth, **2023**, Caracterización bromatológica de la harina de Chima *(Bactris gassipaes)* y estudio de la sustitucion parcial en panes (BSc thesis), Universidad Mayo de San Andrés, La Paz, Bolivia, retrieved from https://docs.google.com/document/d/1tdenEsdWIrGsM2PmzTPV8QiZnFIvRxWI/edit?usp=drive_link&ouid=105776040406896198984&rtpof=true&sd=true .
[22] M. X. Chanataxi Espín, **2015**, Utilización de harina de chonta para la producción de nuevos productos gastronómicos en galletería y su uso dentro de la lonchera escolar en la escuela de educación general básica "Pichincha", parroquia Lloa, cantón Quito, provincia de Pichincha (BSc thesis), Instituto Tecnológico Superior de Turismo y Hotelería, Quito, Ecuador, retrieved from https://www.google.com/url?sa=i&url=http%3A%2F%2F45.184.226.39%2Fbitstream%2F123456789%2F153%2F1%2FHARINA%2520DE%2520CHONTA.PDF&psig=AOvVaw3Gg9xW1bOMCb1BAGTF7FND&ust=1742122241659000&source=images&cd=vfe&opi=89978449&ved=0CAQQn5wMahcKEwiIlsHr-IuMAxUAAAAAHQAAAAAQBA
[23] J. Alemán Reyes, **2019**, Determinación de carotenoides totales en cuatro variedades de mashua (Tropaeolum tuberosum), deshidratada (BSc thesis) Universidad Central del Ecuador, Quito, Ecuador retrieved from http://www.dspace.uce.edu.ec/handle/25000/19948
[24] D. R. Amaya, 'Producción y manejo de datos de composición química de alimentos en nutrición: Análisis de carotenoides', ed. by C. Morón, I. Zacarías and S. de Pablo, Organización de las Naciones Unidas para la Agricultura

y la Alimentación, FAO (UN Food and Agriculture Organization)/Universidad de Chile, Instituto de Nutrición y t-ecnología de los Alimentos, Santiago de Chile, 1997, Cap. 18, retrieved from fao.org/4/ah833s/Ah833s20.htm

[25] J. R. Huayhua Ballivian, 2018, Caracterización de la diversidad morfológica y distribución del Tembe (Bactris gasipaesH.B.K.) nativo en Provincia Ichilo, retrieved from https://1library.co/document/yr6435oy-caracterizaci%C3%B3n-diversidad-morfol%C3%B3gica-distribuci%C3%B3n-bactris-gasipaes-provincia-ichilo.html

[26] A. del P. Riasco Palacios, **2018**, Evaluación de las propiedades físicas y nutricionales de una galleta con inclusión de harina de Chontaduro. Popayan (BSc thesis), Universidad del Cauca, Colombia, retrieved from EVALUACIÓN DE LAS PROPIEDADES FÍSICAS Y NUTRICIONALES DE UNA GALLETA CON INCLUSIÓN DE HARINA DE CHONTADURO (Bactris gasipaes).pdf https://dialnet.unirioja.es/servlet/tesis?codigo=250580

[27] C. Fuentes, R. Castañeda, F. Rengel, J. M. Peñarrieta and L. Nilsson, *Food Chemistry*, 2019, **298**, 15, 125090.

[28] M. Hagos, M. Redi-Abshiro, B. S. Chandravanshi, E. E. Yaya, *Int. J. Anal. Chem.*, 2022, 2022:9363692. doi: 10.1155/2022/9363692. PMID: 35190742; PMCID: PMC8857520.