



Evaluation of the quality of bread obtained with pituca (*Colocasia esculenta* L.) flour

Evaluación de la calidad de pan obtenido con harina de pituca (*Colocasia esculenta* L.)

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ABSTRACT

The impact of pituca flour (*Colocasia esculenta* L.) content on the physicochemical properties and acceptability of Chachapoyan-type bread was examined. The bread formulation involved the substitution of wheat flour with pituca flour at 15/85, 20/80 and 25/75 and a control group 0/100 pituca flour/wheat flour (PF/WF). Physicochemical, farinographic and alveographic analyses were performed on the different flour formulations, while the resulting bread was evaluated in terms of physicochemical properties and sensory quality, including aroma, color and texture. A complete randomized design (CRD) was used to obtain the chachapoyano bread with pituca flour. The comparison between treatments was made using Student's t-test at a significance of 0.05. In addition, a Completely Randomized Block Design (CRBD) was used to evaluate the acceptability variable, using the Tukey test, with a significance level of 0.05. According to the farinographic results, pituca flour was classified as non-bakeable. However, in alveographic terms, the 15/85 flour blend showed close similarities to the control group, both in the flour and in the final bread.

Keywords: alveographic analysis; farinographic analysis; sensory evaluation; formulation; chachapoyan-bread

RESUMEN

Se examinó el impacto del contenido de harina de pituca (*Colocasia esculenta* L.) en las propiedades fisicoquímicas y aceptabilidad del pan tipo chachapoyano. La formulación del pan implicó la sustitución de harina de trigo con harina de pituca en 15/85, 20/80 y 25/75 y un grupo de control 0/100 harina de pituca/harina de trigo (HP/HT). Se realizaron análisis fisicoquímicos, farinográficos y alveográficos en las diferentes formulaciones de harina, mientras que el pan resultante fue evaluado en términos de propiedades fisicoquímicas y calidad sensorial, incluyendo aroma, color y textura. En la obtención del pan chachapoyano con harina de pituca se empleó un diseño completo al azar (DCA). Se realizó la comparación entre tratamientos se hizo mediante la prueba t de Student a una significancia del 0,05. Además, se empleó un Diseño de Bloques Completamente al Azar (DBCA) para evaluar la variable aceptabilidad, utilizando la prueba Tukey, con un nivel de significancia del 0,05. Según los resultados farinográficos, la harina de pituca fue clasificada como no panificable. No obstante, en términos alveográficos, la mezcla de harina 15/85 mostró similitudes cercanas al grupo de control, tanto en la harina como en el pan final.

Palabras clave: análisis alveográfico; análisis farinográfico; evaluación sensorial; formulación; pan chachapoyano



1. INTRODUCTION

Bread is one of the oldest foods, with its origin dating back to Mesopotamia around 6000 B.C., widely consumed in all its presentations worldwide (Vásquez-Lara et al., 2021). Although there are thousands of recipes with alternative inputs to obtain different types of bread, the raw material is relatively simple, primarily wheat flour (Cao et al., 2023; Pico et al., 2015).

Wheat flour is the main cereal used in bread making due to its unique gluten proteins that, when combined with starch, form structures that facilitate gas retention for an elastic, porous product with favorable digestion characteristics after baking (Parenti et al., 2020). In Peru, Chachapoyano bread, also known as “popular Chachapoyas bread,” is a traditional food in the Amazon region, primarily made with wheat flour, water, yeast, and lard, often processed in wood-fired ovens, enhancing its flavor.

In recent decades, bread consumption has rapidly increased in developing countries due to urbanization and industrialization. This, along with climate crises and violent conflicts in wheat-producing regions, has led to an increase in wheat flour prices (Araujo-Enciso and Fellmann, 2020; Queiroz et al., 2021). Consequently, there is a gradual trend to partially or totally replace wheat flour with composite flours from native seeds, cereals, or tubers (Alshawi, 2020; Olagunju et al., 2020; Vásquez-Lara et al., 2021). Some substitutes used are rye (Oest et al., 2020), oats (Carocho et al., 2020; Krochmal-Marczak et al., 2020), sorghum (Ari Akin et al., 2022; Mtelisi Dube et al., 2020), and millet (Sarabhai et al., 2021; Tomić et al., 2020), which have also influenced product characteristics by improving fiber content, rigidity, elasticity, and final product structure (Torbica et al., 2019).

Pituca (*Colocasia esculenta* L.) is a root and tuber species (corm) with great agro-food potential (Púa et al., 2019), resistant to pests and diseases, with high conservation power in natural conditions (Torres-Rapelo et al., 2014). Pituca is a unique food due to its digestibility and hypoallergenic properties provided by its small starch granules, constituting 73-80% of the tuber (Patel and Singh, 2023). Regarding its proximal content, 100 g of dry-weight pituca has approximately 1430 kcal, 9% protein, 26.5% carbohydrates, 2.24% ash, 4.25% fiber, and 0.43% fat (López et al., 2021). In our country, it can be found abundantly in jungle areas, though its local consumption is mainly observed in Amazonian populations, especially in native communities or those knowledgeable about its use (Quispe et al., 2020).

Considering the fluctuating price of wheat grain according to international market management, it is crucial to consider the savings that could benefit from the partial use of pituca flour to obtain Chachapoyano bread with good organoleptic characteristics and consumer acceptability, lowering raw material costs. The study aimed to evaluate the effects of replacing wheat flour with pituca flour on consumer acceptability.

2. MATERIALS AND METHODS

The research was conducted in the pilot plant of the Academic School of Agroindustrial Engineering, Faculty of Agricultural Sciences, National University Toribio Rodríguez de Mendoza of Amazonas, located in the city of Chachapoyas. Pituca samples were sourced from Buenos Aires annex, Bongará province, Amazonas department.

To obtain pituca flour, the tuber was carefully selected and washed before cutting into approximately 1 cm thick pieces, which were boiled for 45 minutes. Then, it was manually peeled using a knife, followed by dehydration in a tray dryer at 65°C for 4 hours with an air velocity of 2 m/s. Finally, it was milled and sieved using a hand mill and sieves of sizes No. 250, 150, and 100. The result of this process is pinkish cream-colored pituca flour.

2.1. Formulation

Table 1 shows the formulation of Chachapoyano bread based on 1000 g of composite flour (wheat and pituca flour).

Table 1.

Formulation of bread substituted with pituca flour

Ingredient	Amount (g)			
	Control (0/100 _{PF/WF})	T1 (15/85 _{PF/WF})	T2 (20/80 _{PF/WF})	T3 (25/75 _{PF/WF})
Wheat flour	1000	850	800	750
Pituca flour	0	150	200	250
Sugar	125	125	125	125
Yeast	3	3	3	3
Salt	183	183	183	183
Lard	208	208	208	208
Dough improver	8	8	8	8
Water	570	570	570	570

For bread preparation, wheat flour and pituca flour were initially dry-mixed according to the corresponding treatment along with yeast (3 g), salt (183 g), and sugar (125 g). The homogenized mixture was placed in the kneading machine (INTEC model A-C50), where dosed amounts of water (570 ml), dough improver (8 g), and lard (208 g) were added. This process was carried out for 10 minutes to develop the gluten.

The resulting dough was formed into a ball and allowed to rest for 5 minutes. Then, using a dough divider machine, small balls were created and rested for 20 minutes. They were shaped into Chachapoyano bread and fermented for approximately 4 hours at a temperature between 35 and 37 °C. Subsequently, the breads were baked at 200 °C for 20 minutes and then cooled for 1 hour at room temperature. Afterward, they were taken to the laboratory for their respective analyses, and the remaining breads were used for the hedonic scale test.

2.2. Physicochemical Analysis

Physicochemical analyses were carried out on pituca flour and Chachapoyano bread samples to determine ash content (AOAC 930.05), fat (AOAC 930.04), protein (AOAC 930.04), and carbohydrates (AOAC 930.09). Additionally, a pH meter (Hanna model, USA) was used to measure pH, and moisture was evaluated using a moisture balance.

2.3. Physicoplastic Characterization

Farinographic (AACC 54-21 method) and alveographic (AACC 54-10 method) analyses were performed at Industrias TEAL S.A. Farinographic analysis evaluated dough consistency from formation, with indices such as water absorption (%), development time (min), dough stability (min), and degree of weakening (BU). Alveographic analysis determined flour behavior in breadmaking, evaluating indices such as dough tenacity (mm), extensibility (mm), work (joules), and gluten characteristics.

2.4. Sensory Evaluation

The sensory evaluation involved 100 untrained panelists aged 25 to 40 years. Participants conducted a 9-point hedonic test to evaluate the attributes of odor, color, taste, and sweetness of each bread treatment substituted with pituca flour. The scale ranged from "dislike extremely" (1) to "like extremely" (9).

Samples were presented in pre-coded plastic bags labeled as: 187 (0/100), 492 (15/85), 314 (20/80), and 521 (25/75). Each bag contained three bread samples for each substitution level and the respective control bread.

2.5. Data Analysis

To evaluate the formulation of Chachapoyano bread substituted with pituca flour, a complete randomized design (CRD) was used. Differences between treatments and control were determined using mean differences under a Student's t-distribution at a 0.05 significance level. For acceptability, a Completely Randomized Block Design (CRBD) was employed, with mean comparison using the Tukey test at a 0.05 significance level.

Experimental data were analyzed using Statgraphics software, and organoleptic analysis was performed using SPSS 15.0.

3. RESULTS

3.1. Proximal Physicochemical Analysis

The physicochemical characterization of the pituca flour used in the experiment yielded results of pH= 6.1 ± 0.01, moisture = 13.23 ± 0.21%, protein = 9.92 ± 0.03%, fat = 1.42 ± 0.01%, carbohydrates = 63.84 ± 0.02%, ash = 2.00 ± 0.01%.

Tables 2 and 3 present the average proximal physicochemical composition, including moisture, protein, fat, carbohydrates, and ash, for flours with different percentages of pituca flour substitution and the resulting breads.

Table 2.

Proximal physicochemical characterization of wheat flour substituted with pituca flour

Parameter	Control (0/100 PF/WF)	T1 (15/85 PF/WF)	T2 (20/80 PF/WF)	T3 (25/75 PF/WF)	F-ratio	p-value
pH	6.56 ± 0.01	6.54 ± 0.01	6.49 ± 0.02	6.20 ± 0.03	12.24	<0.001
Moisture (%)	14.68 ± 0.07	14.31 ± 0.19	14.01 ± 0.15	13.8 ± 3.31	0.39	0.7607
Protein (%)	12.33 ± 0.17	10.47 ± 0.05	10.31 ± 0.02	10.23 ± 0.02	37.39	<0.001
Fat (%)	2.55 ± 0.02	2.40 ± 0.01	2.33 ± 0.01	2.33 ± 0.01	15.264	<0.001
Carbohydrates (%)	57.9 ± 0.1	61.39 ± 0.09	62.12 ± 0.12	62.17 ± 0.02	15.0046	<0.001
Ash (%)	0.55 ± 0.03	0.70 ± 0.03	0.74 ± 0.02	0.75 ± 0.02	36.35	<0.001

Moisture levels in flour mixtures with 20/80 (T2) and 25/85 (T3) PF/WF substitution were considered appropriate according to guidelines established by Quezada et al. (2019), suggesting that moisture content in flour should be between 10% and 14%. Additionally, the protein content shows a decreasing trend, possibly due to the low protein content inherent to this tuber.

Determining ash content is valuable for assessing the purity and yield of cereal flours, as minerals are unevenly distributed across all their layers (Cardoso et al., 2019). The outer layer, comprising the aleurone and pericarp, contains approximately 68%, the starchy endosperm 20%, and the embryo 12% of the total minerals. Therefore, the ash content in breadmaking flour ranges between 0.3% and 0.65%, with higher ash levels indicating less purification and more fine bran and endosperm particles adjacent to the bran (Czaja et al., 2020). The wheat flour used in the research meets breadmaking flour requirements; however, higher substitution levels with pituca flour show an increase in ash content attributed to the higher ash percentage in pituca flour (2%).

Table 3.*Proximal physicochemical characterization of bread with partial substitution of pituca flour*

Parameter	Control	T1	T2	T3	F-ratio	p-value
	(0/100 _{PF/WF})	(15/85 _{PF/WF})	(20/80 _{PF/WF})	(25/75 _{PF/WF})		
pH	6.52 ± 0.01	6.58 ± 0.01	6.00 ± 0.18	5.86 ± 0.12	2.28	<0.001
Moisture (%)	19.48 ± 0.50	19.17 ± 1.55	16.97 ± 0.86	12.75 ± 5.75	3.17	0.0853
Protein (%)	10.07 ± 0.06	8.45 ± 0.01	8.37 ± 0.02	8.25 ± 0.01	188.491	<0.001
Fat (%)	1.09 ± 0.05	1.107 ± 0.07	1.136 ± 0.03	1.178 ± 0.03	19.772	<0.001
Carbohydrates (%)	57.2 ± 0.05	58.44 ± 0.04	60.49 ± 0.06	61.35 ± 0.04	462.305	<0.001
Ash (%)	1.01 ± 0.01	1.45 ± 0.02	1.55 ± 0.04	1.61 ± 0.02	35.376	<0.001

Regarding fat content in the control and treatment groups of the breads, an increase attributable to the addition of lard during the process was recorded (García-Cisneros et al., 2023).

The physicochemical data obtained from the flour mixtures and Chachapoyano bread, including ash, fat, protein, carbohydrates, and pH, show statistically significant differences between treatments and the control group with a 95% confidence level.

3.2. Farinographic and Alveographic Analysis

Table 4 presents the results of the farinographic analysis carried out in the laboratories of Industrias TEAL S.A. for both wheat flour and each level of pituca flour substitution. This analysis evaluated dough consistency through the force required for its mixing at a constant speed and the water absorption necessary to reach a standard force of 500 BU in farinographic tests.

Table 4.*Farinographic characteristics of wheat and pituca flour mixtures for different levels of substitution*

Treatment	Substitution Level (%)	Water Absorption (%)	Development Time (min)	Stability (min)	Weakening (Brabender Units)
T0 (0/100 _{PF/WF})	0	64.8	12.5	8.7	40
T1 (15/85 _{PF/WF})	15	64.6	5.1	3.7	80
T2 (20/80 _{PF/WF})	20	67.6	4.9	3.3	95
T3 (25/75 _{PF/WF})	25	68.4	4.7	3.1	105

According to the table above, water absorption in the dough treatments T0 and T1 showed medium hydration levels between 58% and 65%, ideal for forming viscoelastic doughs. It is important to note that water absorption is related to the water requirement for gluten to reach a standard force of 500 BU in farinographic tests (Vásquez-Lara et al., 2021). Additionally, water absorption percentage increases proportionally to the substitution level, indicating that pituca flour has a higher water absorption capacity than wheat flour, possibly due to the increased carbohydrates from pituca starch (75% amylopectin and 25% amylose), which have equal or higher values of hydrophilic constituents (amylose) (Morales, 2012). According to Solarte-Montúfar et al. (2019), amylose content in starch is the determining factor for the quality of finished foods, as high values favor greater solubility, higher viscosity, better paste clarity, and greater gel retrogradation tendency.

According to Pantanelli (2009), the time required to reach maximum dough consistency ranges from 10 to 20 minutes. The evaluated wheat and pituca flour mixtures presented short development times (≤ 5.1 min.). Similarly, dough stability plays an important role in better fermentation development and tends to be stronger. According to Hernández et al. (2023), the minimum stability time required in the baking industry is 8 minutes, which is higher than the times obtained in the evaluated partial substitution

treatments. Lastly, the weakening index of the substitution treatments decreased between 40 and 105 Brabender Units (BU), reflecting low quality in breadmaking flours.

According to Sandoval et al. (2012) and Islas et al. (2005), the farinographic analysis results for development time, stability, and dough weakening in wheat and pituca flour mixtures indicate a deficient gluten network or damaged starch presence that could be linked to the protein quantity and gluten formation in the doughs due to substitution flour, making the flour unsuitable for breadmaking. The obtained results align with research conducted on bread production with the addition of tuber flours (Vázquez-Chávez and Hernández-López, 2023), cassava (Hernández et al., 2023), and potato (Miranda, 2023), showing a decrease in farinographic dough characteristics with increased tuber flour in the flour mixture.

Table 5 presents the results of the alveographic analysis of wheat and pituca flour mixtures for different substitution levels. Regarding tenacity (P), representing the maximum pressure the dough can withstand before deforming, treatment T1 exhibited the best performance with an acceptable value of 987 mm. In contrast, values for treatments T2 and T3 were above the minimum suitable value for bread production ($P \leq 100$).

Table 5.

Alveographic characteristics of wheat and pituca flour mixtures for different substitution levels

Treatment	P (Tenacity) mm	L (Extensibility) mm	P/L	W (Work)	Gluten Characteristics
T0 (0/100 PF/WF)	103	84	1.22	192	Weak
T1 (15/85 PF/WF)	87.8	80.0	0.9	230	Strong
T2 (20/80 PF/WF)	98.7	82.8	1.19	202	Weak
T3 (25/75 PF/WF)	102.2	83	1.21	196	Weak

Flour quality is also measured by its balance between resistance to deformation (P) and extensibility (L) as this favors obtaining bread with maximum volume and well-proportioned internal structure. Therefore, a P/L ratio < 1.5 is considered suitable for breadmaking according to Calaveras (1996). Compared to the obtained test results, the P/L ratio was less than 1.5, indicating that it is breadmaking flour.

3.2. Sensory Evaluation

Figure 1 shows the sensory evaluation results applied to breads made with wheat and partial pituca flour substitution. Consumer preferences for new products can provide valuable information about the studied product (Thompson et al., 2004), allowing the observation of individual variations among them along with the descriptive sensory relationship (Issanchou, 1996).

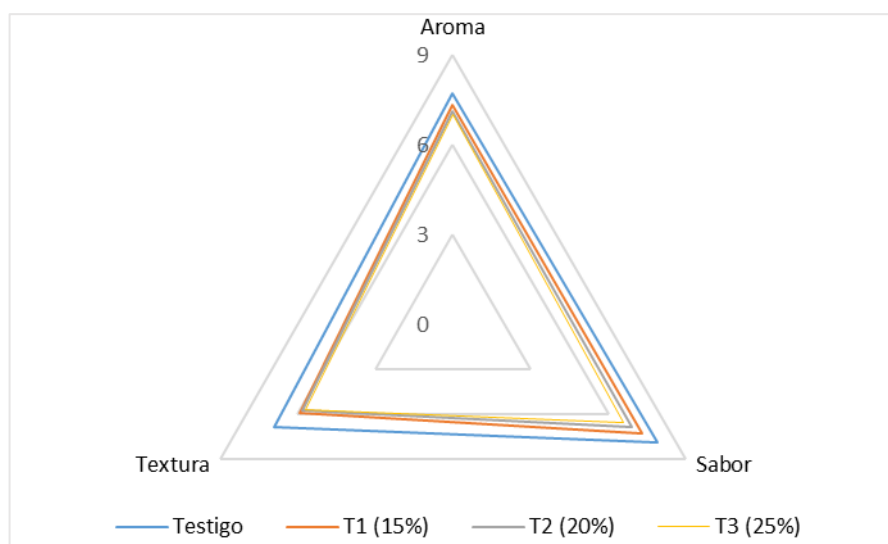


Figure 1. Analysis of sweetness, aroma, and flavor attributes of bread made with wheat flour (control) and breads made with partial pituca flour substitution

Regarding Chachapoyano bread made from flours substituted with pituca, while the evaluated attributes decreased in their rating with increased pituca flour, treatment T1 (15/85 PF/WF) showed higher acceptance in the analyzed parameters among the evaluated substitution formulations, obtaining a rating of "like moderately" (7.3) in the flavor and aroma attribute and a rating of "slightly soft" (5.9) in the texture attribute.

Table 6 shows the averages of the sensory evaluations and Tukey test results ($P < 0.05$) applied to breads made with wheat flour and partial pituca flour substitution. According to this, treatment T1 (15/85 PF/WF) presents significant differences concerning the other treatments in the flavor attribute and significant differences concerning the control treatment (T0, 0/100 PF/WF) in the aroma and texture attributes.

Table 6.

Mean comparison by Tukey method in evaluated attributes in breads made with partial pituca flour substitution and wheat flour (control)

Treatment	Aroma	Flavor	Texture
T0 (0/100 PF/WF)	7.7 ± 1.5698a	7.9 ± 1.0825a	6.9 ± 0.7035a
T1(15/85 PF/WF)	7.3 ± 2.0201b	7.3 ± 2.0201b	5.9 ± 1.6697b
T2 (20/80 PF/WF)	7.1 ± 1.8963b	6.9 ± 1.6697c	5.8 ± 1.3333b
T3 (25/75 PF/WF)	7.0 ± 1.7978b	6.6 ± 1.3333d	5.7 ± 1.3521b

*Treatments with the same letter are not significantly different according to Tukey test ($P < 0.05$).

CONCLUSIONS

From the physicochemical profile, alveographic analysis, and sensory analysis of Chachapoyano breads obtained with partial wheat flour substitution, treatment T1 (15/85 PF/WF) presents better conditions compared to wheat flour. However, in farinographic evaluation terms, it indicates non-breadmaking characteristics.

The present research results show that using pituca flour is a good alternative for breadmaking, especially in the Amazon where wheat is not produced, allowing value addition to pituca with minor substitutions to diversify its use.

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CONFLICT OF INTERESTS

There is no conflict of interest related to the subject matter of the work.

CONTRIBUTION OF THE AUTHORS

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