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Evaluation of INIA Real Sicaina and Shulay Potato Varieties for Industrial Processing as Frozen Pre-Fried Potatoes: (A Case Study for the Peruvian Agro-Industry)

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Abstract

The study evaluated the INIA Real Sicaina and Shulay potato varieties for processing as frozen pre-fried potatoes, given the growing interest in the Peruvian agroindustry. These varieties were compared with imported ones under blanching and pre-frying treatments, highlighting the lack of prior research on local varieties.
The main challenge lies in Peru's technological gap, where frozen pre-fried potatoes are not produced due to raw material quality and limited processes. This research tested new varieties and analyzed the impact of treatments on key indicators like color and moisture. The results showed that these varieties have the potential to meet industrial standards, especially under HTST treatment, with the Real Sicaina variety achieving comparable quality levels to imported varieties This work promotes the development of the Peruvian agroindustry, providing a foundation for future research on optimized processes and new potato-based products.

Keywords

Potato, blanching, pre-fried potato, color, moisture.

1. Introduction

The average global potato consumption is 33 kg per person. However, in Peru, consumption reached 90 kg per person in 2019. GlobeNewswire (2021) notes that the global demand in the processed potato market was valued at 31 800 million dollars in 2019 and forecasts that by 2030 it will reach 51 100 million dollars. The main segments of this market are chips and extruded snacks, frozen, and dehydrated products, in that order of size. Between 2015 and 2019, the importation of potatoes in the frozen segment increased. It was found that importing companies possess improved potato varieties, advanced production system management, and technology development that allow them to add value to the raw material (SSE 2020). This represents a competitive advantage. In contrast, in Peru, the predominant production lines focus on the supply of fresh potatoes through simple processes such as washing and intermediate transformation (Ordinola 2021; SSE 2020). National companies that supply chopped potatoes indicate that they do not produce frozen pre-fried potatoes because the final product was deemed unsuitable for consumption due to the quality of the available raw material and the technology applied in its production (Ministry of Agriculture and Irrigation MINAGRI 2020).

Peru leads potato production in Latin America and boasts a constant supply (SSE 2020). Therefore, it is necessary to contribute to the development of an agro-industry based on this raw material, even though this process is still in its early stages (Ordinola 2021). Entities such as The National Institute of Agrarian Innovation (INIA) conducts

ongoing research in areas related to agriculture, including the development of new varieties, high-quality seeds, new technologies, and training for farmers. Additionally, the headquarters of the International Potato Center (CIP), where research and food development are also carried out, focuses on improving yields, quality, nutrition, income, and natural resource management. Based on the above, the need to develop the market for processed potatoes in Peru becomes evident. Therefore, it is necessary to start by identifying varieties with potential for processing, then conduct physical and chemical tests on them, and finally perform a comparative analysis against the imported product to determine if they are suitable for processing as frozen pre-fried potatoes, as also suggested by Ordinola (2021) and SSE (2020).

1.1 Objectives

This research evaluates the possibility of using the potato varieties released by INIA, Real Sicaina, and Shulay, as frozen pre-fried potatoes. The aim is to determine the effect of the treatments applied during the processing of imported products, such as blanching and sequential pre-frying HTST and LTLT on color and moisture variables to establish a baseline for the time and temperature to be applied. Finally, a comparison will be made between the results of the indicators obtained from the national varieties and those from imported varieties to assess their performance. Several samples of frozen pre-fried potatoes were made from potatoes obtained from the Santa Ana Agricultural Experiment Station in Junín, Peru. The samples will undergo color and moisture analysis.

2. Literature Review

During the literature review, it was found that, in the processing of frozen pre-fried potatoes, the exposure time and temperature during the blanching and frying stages are the most relevant factors (Othman and Jamil 2021; Trejo-Escobar et al. 2019), as these factors influence the desirable color and flavor of the food (Ananey-Obiri et al. 2018; Wang et al. 2023). However, the effects of low-temperature long-time (LTLT) and high-temperature short-time (HTST) blanching and frying treatments have not been investigated in many varieties (Ngobese et al. 2017).The varieties used in the industry have an oblong, elongated, and oval shape, with a diameter greater than 5 cm. Regarding dry matter content, authors and industry experts agree that it should be between 20 % and 24 %, as this allows for crispier potatoes (Lara and Malaver 2019; Ngobese and Workneh 2017).

The production process of frozen pre-fried potatoes consists of the following stages: washing, peeling, cutting, blanching, partial pre-frying, and freezing before the final frying (Jaggan et al. 2020; Millin et al. 2016; Ngobese et al. 2017). Blanching is the stage where the potatoes are immersed in water at a specific temperature and time to inactivate enzymes, improve texture, preserve color, flavor, and nutritional value, as well as reduce moisture loss during frying, resulting in lower oil absorption (Chhe et al. 2018; Wang et al. 2023). Studies indicate that the enzyme responsible for discoloration is most active at temperatures between 100-140 ºC (Yu et al. 2010), and it is suggested that temperatures above 94 ºC are more effective (Chhe et al. 2018). However, Bingol et al. (2014) observed complete inactivation at 70 ºC for 16 minutes.

Regarding the quality parameters evaluated in potato fries derived from frozen pre-fried potatoes, several authors have investigated indicators such as moisture content and color (Millin et al. 2016; Ngobese et al. 2017; Baltacıoğlu 2017; Othman and Jamil 2021). In commercial varieties such as Innovator, Russet Burbank, and Bintje (Aviko 2020; Farmfrites 2021; McCain 2014). Color plays a critical role in consumer acceptance and can influence whether a product is consumed or not (Abong et al. 2009; Michalak et al. 2019). Additionally, there is a direct relationship between the surface browning of potatoes and acrylamide content, making color an indicator of this substance (Lara and Malaver, 2019; Michalak et al. 2019). As for moisture, it is estimated that potato fries should have an average of 45.83% to maintain good texture and avoid issues associated with higher moisture content (Mesias et al. 2019).According to the reviewed literature, no articles focused on the processing of frozen pre-fried potatoes based on Peruvian potato varieties have been found. However, several studies highlight the importance of temperature and exposure time in the blanching and pre-frying stages in potato processing.

3. Methods

The focus of this research is quantitative, as it follows a process with stages that must be executed sequentially to test the proposed hypothesis. This approach allows for the collection of the intended measurements and the analysis of the results obtained. This is an experimental design, conducted in a controlled environment where independent variables are manipulated to observe their effects on dependent variables (Hernández-Sampieri and Mendoza, 2018). The research pathway is presented in Figure 1.

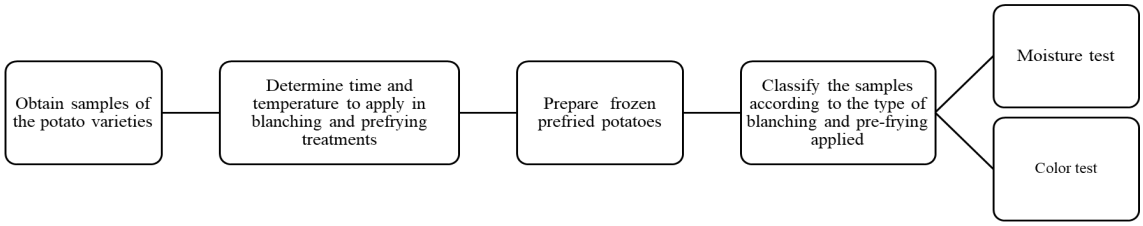

Figure 1. Structure of the experiment

The first stage will involve obtaining the varieties INIA 326 - Shulay and INIA 319 - Real Sicaina, which have been specifically developed for the industry. Their selection was based on an analysis of their physical characteristics and dry matter content, as they were found to have dry matter ranges of 23-27% and 22-24%. The physical characteristics observed include an oval shape, shallow eyes, and white and cream-colored flesh, respectively. Based on the aforementioned characteristics, these varieties are optimal for study after processing them as frozen pre-fried potatoes. The physical appearance of the varieties under study is shown in Figure 2.

Figure 2. Variety of Real Sicaina and Shulay Potatoes

Next, the HTST and LTLT blanching treatments and HTST and LTLT pre-frying treatments shown in Table 1 will be applied according to the times and temperatures proposed by Ngobese et al. (2017) during the process of making the pre-fried potatoes. Finally, after obtaining the samples for analysis, the variables observed in response to the experimental conditions will be moisture and color.

Table 1. Time and temperature of blanching treatments and pre-frying HTST and LTLT (Adapted from Ngobese et al. 2017)

Variables	Treatments			
	Blanching		Pre-frying	
	LTLT (A)	HTST(B)	LTLT(A)	HTST(B)
Temperature	75ºC	85ºC	160ºC	180ºC
Time	10 min	5 min	2 min	1 min

The process for preparing frozen pre-fried potatoes involved washing, weighing, and peeling 5 kg of each variety of potato using a generic model mechanical peeler. Next, the potatoes were cut into strips of 1 cm x 1 cm with a manual cutter, and through quality control, potatoes shorter than 5 cm and/or with defects were discarded. Subsequently, the potatoes were washed and the blanching and frying stages were carried out using the treatments proposed by Ngobese and Workneh (2018) and Ngobese et al. (2017).

Each batch of washed potatoes will be divided into two groups. The first group will be blanched using the LTLT treatment (75 °C for 10 minutes), while the second group will undergo the HTST treatment (85 °C for 5 minutes). Both treatments will use a potato-to-water ratio of 3:4 (kg/L). Each group will be dried in an oven at 85 °C for 10 minutes and then further divided into two sub-groups. The first sub-group will be pre-fried using the LTLT method (160 °C for 2 minutes), and the second sub-group will be pre-fried using the HTST method (180 °C for 1 minute). Both pre-frying processes will use palm olein and a potato-to-oil ratio of 1:10 (g/mL). The oil will be replaced after every four fryings and replenished to the initial level after each use. Once this stage is complete, the potatoes will be drained, allowed to cool, placed in BPA-free airtight bags, labeled, and frozen at –18 °C.

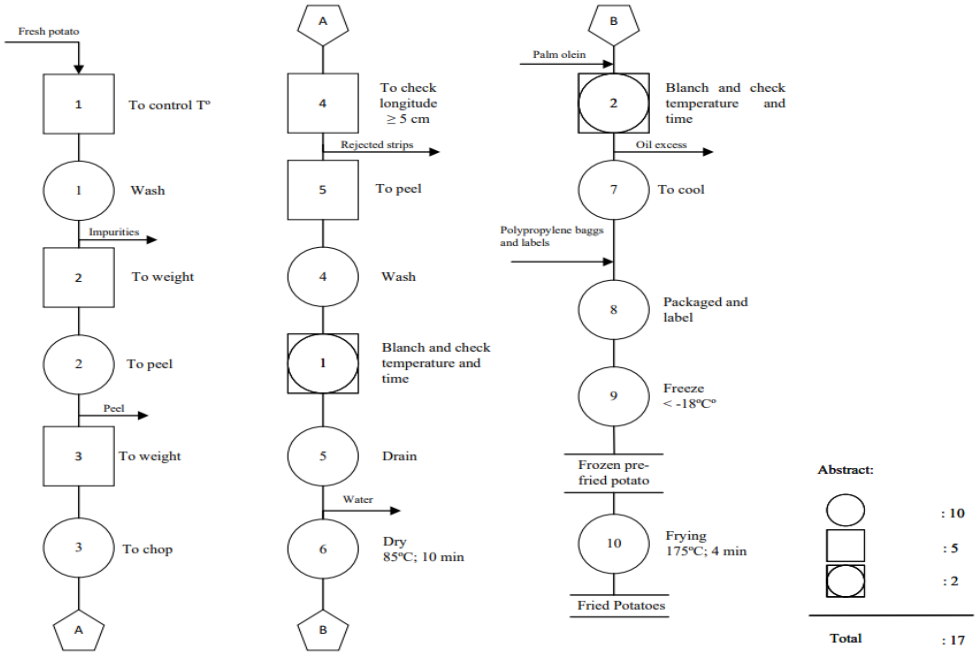

Figure 3. Operation diagram of the process for the production of frozen pre-fried potatoes

After 45 days, the frozen French fries will be fried at 175 °C for 4 minutes per batch, and the following tests will be conducted:

Color test:
Random samples of French fries will be taken to the Laboratory of Docimasia at the University of Lima, where a ColorTec PCM colorimeter will be used to perform measurements at 3 random points on each stick. The readings will be expressed as chromatic coordinates L*, a*, and b*, representing lightness-darkness (0-100), red-green (negative and positive values), and blue-yellow (negative and positive values) respectively of the samples. This test was conducted similarly in the study by Ngobese et al. (2017).

Moisture test:
The measurement of moisture content (% on a wet basis) will be carried out using the AOAC 930.04:2019 method established by the Association of Official Analytical Chemists. This method stipulates that samples of 150 g should be dried at 100-105 ºC until a constant weight is reached. The percentage obtained will represent the weight lost during drying.

Statistical Analysis:
The results from the color and moisture tests will be analyzed using Minitab Statistical Software (version 20). ANOVA (Analysis of Variance) will be employed to examine the differences among the variables.

The results from the tests will determine whether the Real Sicaina and Shulay varieties, in terms of moisture and color, have the potential to be processed as frozen pre-fried potatoes using the LTLT (Low-Temperature Long-Time) and HTST (High-Temperature Short-Time) blanching and pre-frying treatments. The indicators will be calculated based on the variables outlined in Figure 4.

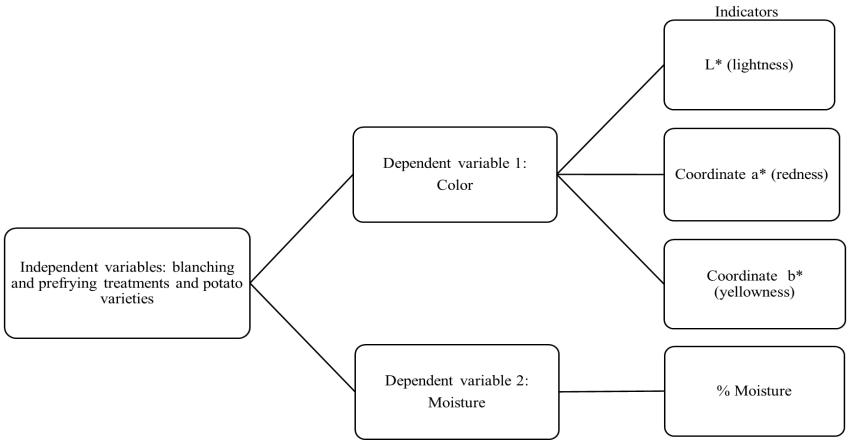

Figure 4. Variables and indicators

4. Data Collection

Frozen pre-fried potatoes were prepared using the process described in Figure 3.

Table 2. Combinations of blanching and pre-frying treatments

Combinations	Treatments	
	Blanching	Pre-frying
AA	LTLT: 75ºC / 10 min	LTLT: 160ºC / 2 min
AB	LTLT: 75ºC / 10 min	HTST: 180ºC / 1 min
BA	HTST: 85ºC / 5 min	LTLT: 160ºC / 2 min
BB	HTST: 85ºC / 5 min	HTST: 180ºC / 1 min

It is worth noting that each potato variety was divided into 3 batches with 2 replicates to gather data for each of the 4 treatment combinations outlined in Table 2. Consequently, 24 samples or sticks were obtained for each variety for analysis, as shown in Figure 5.

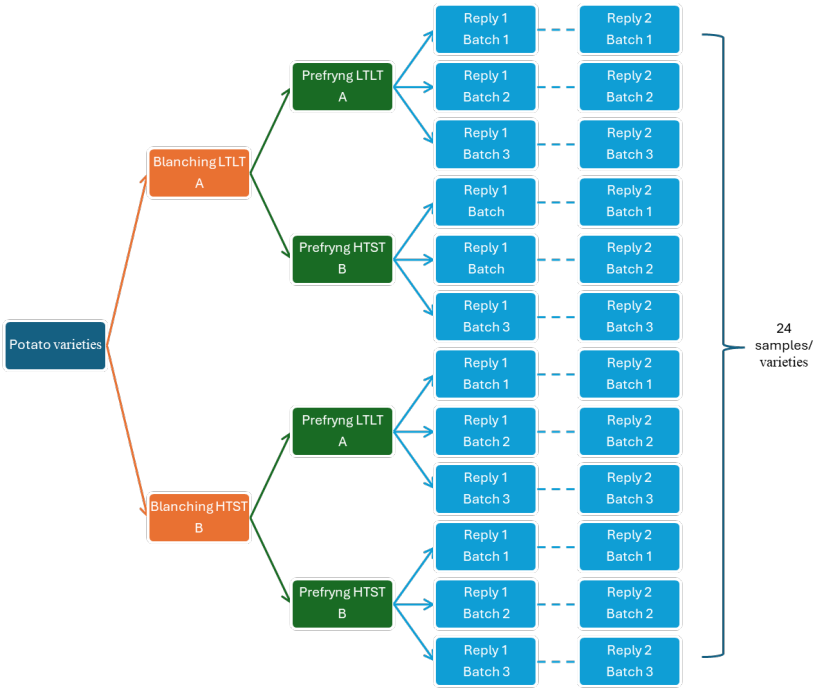

Figure 5. Sample Collection by Variety, Blanching, and Pre-Frying

5. Results and Discussion

5.1 Numerical Results

The color and moisture indicators were measured after frying the frozen pre-fried potatoes. The results obtained from the color indicators are shown in Table 3.

Table 3. Indicators of color

Treatments		L*		a*		b*	
Blanching	Pre-frying	Real Sicaina	Shulay	Real Sicaina	Shulay	Real Sicaina	Shulay
LTLT 75ºC/10min	LTLT 160ºC/2min	32.44	38.09	-12.1	7.68	17.45	13.80
LTLT 75ºC/10min	HTST 180ºC/1min	35.55	33.06	5.65	12.62	16.95	17.63
HTST 85ºC/5min	LTLT 160ºC/2min	35.77	41.78	-1.13	14.64	17.82	23.97
HTST 85ºC/5min	HTST 180ºC/1min	38.33	40.57	4.91	15.02	15.37	12.90

Regarding luminosity and the b* coordinate, it can be observed that both varieties show similar values for each combination of treatments. In contrast, the* coordinate displays a greater difference between the results for each variety. Table 4 presents the results for the moisture indicator, where it is observed that, regardless of the processing treatments, the average moisture content of the varieties exceeds 45.83% (Mesías 2019). Additionally, the values do not show much variation.

Table 4. Percentage of moisture content

Treatments		Moisture Content	
Blanching	Pre-frying	Real Sicaina	Shulay
LTLT 75 ºC /10 min	LTLT 160 ºC / 2 min	52.25	50.75
LTLT 75 ºC / 10 min	HTST 180 ºC / 1 min	53.35	52.25
HTST 85 ºC / 5 min	LTLT 160 ºC / 2 min	50.95	49.55
HTST 85 ºC / 5 min	HTST 180 ºC / 1 min	54.20	49.9

5.2 Graphical Results

Subsequently, following the proposed methodology, the corresponding statistical analyses were conducted to find significant differences between varieties and processing treatments.

Luminosity (L*):

From the variance analysis, it was found that there are significant differences in luminosity between the potato varieties and the blanching treatments in this study ($p<0.05$); however, no significant differences were found between the pre-frying treatments. The study by Ngobese et al. (2017) supports our research, indicating that luminosity shows significant differences between varieties but not for pre-frying treatments.As shown in Figure 6, the Real Sicaina variety exhibited the highest luminosity value (38.33) using HTST blanching and HTST pre-frying; however, the Shulay variety showed a higher value (41.78) with HTST blanching and LTLT pre-frying treatments.

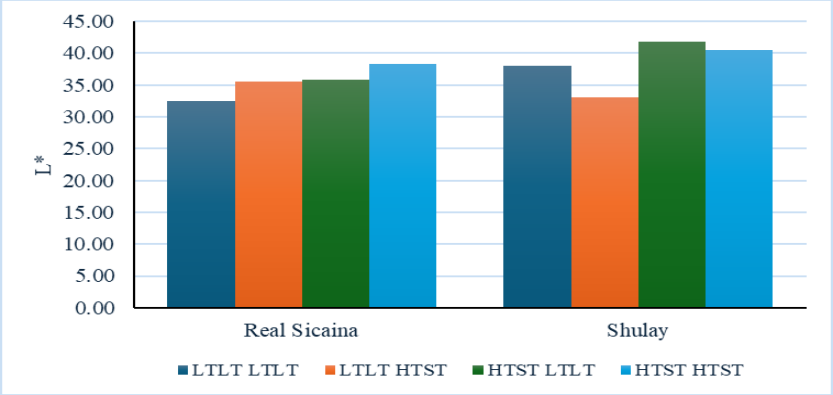

Figure 6. Luminosity by variety, blanching, and pre-frying

Coordinate a* (redness): From the analysis of variance, it was found that this indicator showed significant differences between varieties ($p<0.05$), unlike the bleaching and pre-frying treatments ($p>0.05$).

It was found that only the Real Sicaina variety, when applying the HTST bleaching and LTLT pre-frying treatments, presents a value close to what was expected for this indicator. Therefore, although it cannot be claimed that the treatments influence this outcome, it can be determined that the Real Sicaina variety yields better results than the Shulay variety, as shown in Figure 7.

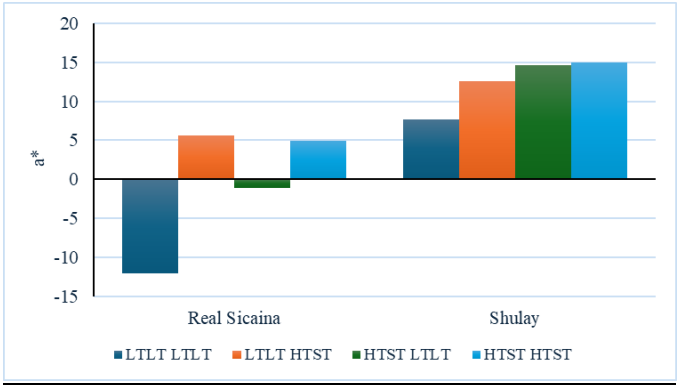

Figure 7. Coordinate a* by variety, blanching, and pre-frying

Coordinate b* (Yellowness):
It is important to note for this indicator that the data did not meet the assumption of normality ($p<0.05$) as observed in Figure 8. This may be due to the time elapsed between frying and color analysis.

Figure 9 shows that the highest values for this indicator were found for both varieties with the HTST blanching and LTLT pre-frying treatments.

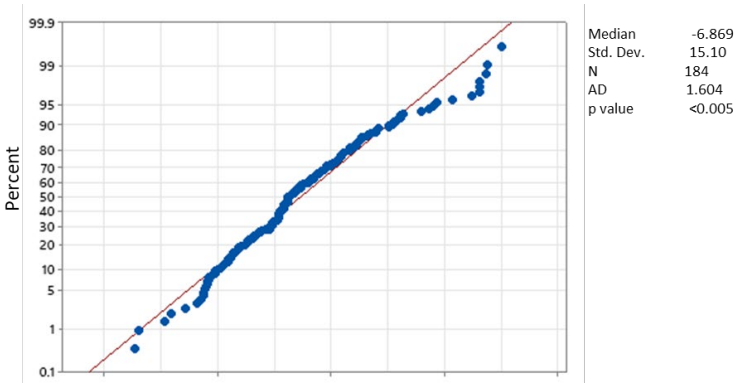

Figure 8. RESI probability graph

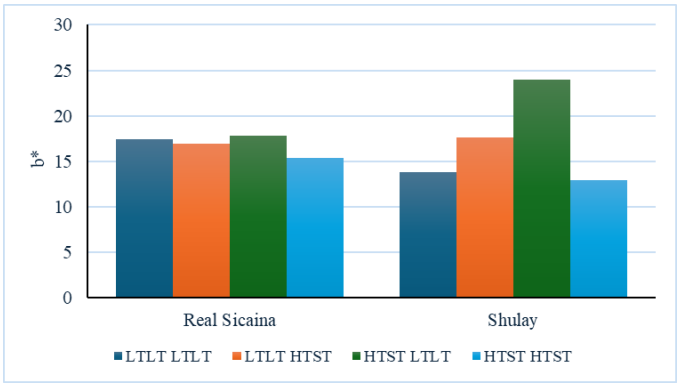

Figure 9. Coordinate b* by variety, bleaching, and pre-frying treatment

Moisture:
Based on the analysis of variances, it was found that this indicator showed significant differences between varieties ($p<0.05$), unlike the blanching and pre-frying treatments ($p>0.05$). Therefore, it cannot be stated that the treatments influence this result.

As seen in Figure 10, the lowest value was obtained by the Shulay variety with HTST blanching and LTLT pre-frying (49.55%). However, this still exceeds the recommended moisture percentage.

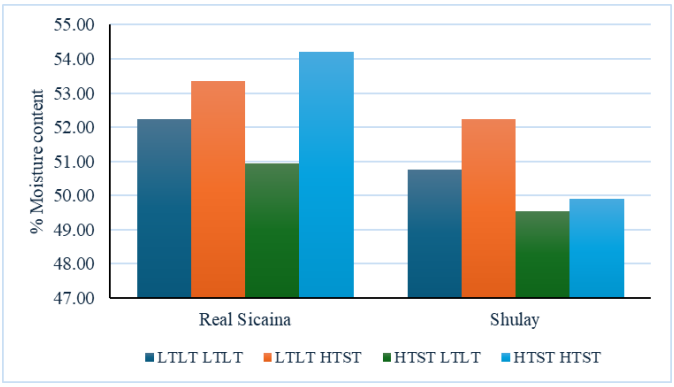

Figure 10. Moisture content by variety, blanching, and pre-frying treatment

5.3 Proposed Improvements

Regarding the technological feasibility during the process of producing frozen pre-fried potatoes, the equipment used was non-industrial. Therefore, for future studies, it is suggested to seek equipment similar to that used by importing companies to achieve a more controlled process in terms of temperature and time. For color and moisture analysis, standard industry procedures were employed, such as colorimeters and international treatments

like AOAC 930.04:2019 for moisture analysis. It is important to note that due to logistical limitations, the samples were analyzed several hours after their final frying, which may have influenced the results. To avoid changes in the sample composition due to the elapsed time between the final frying and the color and moisture tests, it is recommended to conduct the study in a laboratory equipped with these instruments or, alternatively, for the researchers to acquire them.

Regarding the commercial viability of the raw material, only 5 kg per variety was available. This limited the number of samples that could be analyzed. It is recommended to increase the volume of raw material to allow for more replicates and to conduct a new study, particularly focusing on the b* color indicator. On the other hand, it is advisable to vary the time and temperature in the bleaching and pre-frying treatments to observe changes in color and moisture results.

5.4 Validation

This chapter aims to provide a detailed analysis of the findings and compare them with previous research conducted on commercial potato varieties.

Luminosity (L)*

Previous research recommends that the commercial varieties Innovator and Russet Burbank should use LTLT blanching treatments and HTST pre-frying, which resulted in 57% and 60%, respectively (Ngobese et al., 2017; Bingol et al., 2014). However, this study found that the highest luminosity value for the Real Sicaina variety was obtained with HTST blanching and HTST frying, while for the Shulay variety, it was achieved with HTST blanching and LTLT frying.

The studies by Ngobese et al. (2017) and Ngobese and Workneh (2018) agree that the effects of the studied treatments vary among varieties due to the genotype of the raw material. They also found that the luminosity for the Innovator variety ranged between 55-60, while for the Shulay variety, it ranged between 33-41, and for the Real Sicaina it ranged between 32-38. Morón et al. (2013) propose that for the Yungay variety, the optimal values are between 87-90. This demonstrates that the genotype of the varieties has an effect on this variable.

Coordinate a*

Ngobese et al. (2017) found that the values for the Innovator variety ranged from -1.1 to 0.4 for the a* coordinate. In this study, only the Real Sicaina variety, using the HTST blanching treatment and LTLT frying, fell within this range, specifically at -1.1. The same value was found for the Innovator variety using the same treatments.

On the other hand, the study by Mesias et al. (2021) indicates that the value for this indicator should not exceed 0.855, as it influences consumers' decisions to opt for preparing fries using the frying process. Exceeding this value would result in the formation of the carcinogenic substance Acrylamide. Similarly, Michalak et al. (2019) also found that this substance appears when the values of the a* coordinate are high.

Coordinate b*

The analyzed samples showed results between 15-23 for this indicator, whereas the Innovator variety analyzed by Ngobese et al. (2017) had values between 20-23. The yellowness in the samples can be visualized in Figure 11 and Figure 12.

Figure 11. Samples of potato fries from the Shulay variety

Figure 12. Samples of potato fries from the Real Sicaina variety

Regarding moisture, Ngobese et al. (2017) studied the Innovator potato variety and obtained results consistent with the study. The authors attributed these results to the genotype of the varieties and the narrow differences in the time and temperature treatments analyzed. Despite this, it was noted that the best treatments for processing the Innovator variety were LTLT blanching and HTST frying due to their effects on physical and sensory quality. It was found that the Innovator potato had a moisture content of 46%. Sanz et al. (2007) found a moisture content of 52% for the Bintje variety, and Bingol et al. (2014) found 47% for the Russet Burbank variety, with the Innovator variety being closer to the ideal 45.83% (Mesías et al. 2019). Therefore, as shown in the Shulay variety, it tends to be in a range similar to commercial potatoes.

In summary, the results presented by the color indicators demonstrate that the brightness of the fries depends on the variety, and despite being below the values of imported varieties, this can be explained by their genotype. On the other hand, the a* coordinate did present the same value as its imported counterpart. Finally, regarding moisture percentage, it was found that although the values are not close to the optimal proposed by Mesías et al. (2019), the Shulay variety is closer to commercial varieties.

6. Conclusion

The main finding of this study indicates that HTST blanching (85ºC for 5 minutes) affects the L* brightness for both the Real Sicaina and Shulay varieties. However, no significant differences were found between the processing treatments for the other indicators, only between varieties. For lightness, both varieties showed ranges

below those found for the Innovator variety. For the a* coordinate, the Real Sicaina variety exhibited the same value (-1.1) as the imported Innovator variety. For the b* coordinate, the ranges of the varieties studied were close to the Innovator variety. For moisture, the Shulay variety was found to have a moisture percentage similar to the commercial varieties Russet Burbank and Bintje. Although most of the treatments used in processing did not influence the color and moisture indicators, comparisons with commercial varieties revealed similarities. Therefore, it can be concluded that these varieties have the potential to be suitable for agroindustry. However, further frying tests are necessary to determine the ideal processing for each variety.

The importance of this study lies in identifying varieties with potential for processing as frozen pre-fried potatoes. A process and base treatments for blanching and pre-frying were determined, and color tests were conducted to make comparisons with imported varieties, thereby identifying strengths and weaknesses in the new varieties developed in Peru. Therefore, our contribution to the development of the processed potato agroindustry consists of setting a precedent for future research on the Real Sicaina and Shulay varieties. Finally, it is recommended to use industrial equipment during the process and to have precise measuring instruments to achieve more accurate results. For future research, it is suggested to analyze a larger number of samples and test different combinations of time and temperature in blanching and pre-frying treatments. Additionally, analyses should be conducted immediately or shortly after the final frying to avoid alterations in the composition of the samples.

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