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Physical and sensory quality of coffee dried in three prototypes of greenhouse solar dryers

Calidad física y sensorial del café secado en tres prototipos de secadores solares tipo invernadero

Qualidade física e sensorial do café seco em três protótipos de secadores solares de estufa

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Abstract

Reducing the drying time of coffee without causing negative effects on cup quality has been the subject of several investigations. The objective was to determine the effect of three variants of a greenhouse-type solar dryer prototype on the physical, sensory and microbiological quality of coffee. The solar dryer prototype with three variants, prototype 1 (P1) greenhouse solar dryer, prototype 2 (P2) solar dryer with air extractor and prototype 3 (P3) solar dryer with air extractor and solar powered heaters, was compared to traditional drying (T0) (cement floor). Drying time, physical grain defects, yield, sensory and microbiological quality were evaluated. The best results were obtained in P3 with a drying time of 52 h (2 ¼ days), with dry parchment coffee beans without primary defects, higher yield in exportable gold coffee (83.24 %), sensory profile of 84.25 points qualified as specialty coffee (with Q Premium grade) and better safety than coffee obtained by traditional drying; demonstrating that the greenhouse type solar dryer with air extractor and solar energy heaters is a sustainable alternative to improve the efficiency of coffee drying while preserving its sensory quality, an essential value for producers to achieve better prices.

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Resumen

Reducir el tiempo de secado del café sin ocasionar efectos negativos en la calidad en taza ha sido motivo de diversas investigaciones. El objetivo fue determinar el efecto de tres variantes de un prototipo de secador solar tipo invernadero en la calidad física, sensorial y microbiológica del café. El prototipo de secador solar con tres variantes, prototipo 1 (P1) secador solar tipo invernadero, prototipo 2 (P2) secador solar con extractor de aire y prototipo 3 (P3) secador solar con extractor de aire y calefactores con energía solar, fueron comparados con el secado tradicional (T0) (piso de cemento). Se evaluó tiempo de secado, defectos físicos del grano, rendimiento, calidad sensorial y microbiológica. Los mejores resultados se obtuvieron en el P3 con un tiempo de secado de 52 h (2 días ¼), con granos de café pergamino seco sin defectos primarios, mayor rendimiento en café oro exportable (83,24 %), perfil sensorial de 84,25 puntos calificado como café especial grado Q Premium y mejor inocuidad que el café obtenido por secado tradicional; demostrando que el secador solar tipo invernadero con extractor de aire y calefactores con energía solar es una alternativa sostenible para mejorar la eficiencia del secado del café preservando su calidad sensorial, valor imprescindible para que los productores logren mejores precios.

Palabras clave: cafés especiales, invernadero, catación, sensorial, inocuidad.

Resumo

A redução do tempo de secagem do café sem efeitos negativos na qualidade da chávena tem sido objeto de vários estudos de investigação. O objetivo era determinar o efeito de três variantes de um protótipo de secador solar de estufa na qualidade física, sensorial e microbiológica do café. O protótipo de secador solar com três variantes, o protótipo 1 (P1) secador solar de estufa, o protótipo 2 (P2) secador solar com extrator de ar e o protótipo 3 (P3) secador solar com extrator de ar e aquecedores solares, foi comparado com a secagem tradicional (T0) (chão de betão). Foram avaliados o tempo de secagem, os defeitos físicos do grão, o rendimento, a qualidade sensorial e microbiológica. Os melhores resultados foram obtidos em P3 com tempo de secagem de 52 h (2 ¼ dias), com grãos de café pergaminho secos sem defeitos primários, maior rendimento em café ouro exportável (83,24 %), perfil sensorial de 84,25 pontos qualificado como café especial (com grau Q Premium) e melhor segurança que o café obtido por secagem tradicional; demonstrando que o secador solar tipo estufa, com extrator de ar e aquecedores de energia solar, é uma alternativa sustentável para melhorar a eficiência da secagem do café, preservando sua qualidade sensorial, valor essencial para os produtores alcançarem melhores preços.

Palavras-chave: cafés especiais, estufa, degustação, sensorial, segurança.

Introduction

Currently coffee producers are looking for new processing techniques to improve their quality and achieve differentiated sensory profiles for international markets (Osorio *et al*., 2022), according to the same author, after harvesting the coffee cherries, they are pulped, fermented and washed, immediately followed by drying, dehydrating the bean until it reaches a humidity that guarantees its conservation and stability. This process can be carried out mechanically, in raised beds or patios in order to reduce humidity to 10 to 12 %, thus obtaining a more stable product in storage (Torres-Valenzuela *et al*., 2019). Traditional drying in cement patios or blankets directly to the ground take advantage of solar energy that is often varied due to climatic conditions (Prada *et al*., 2019), as often occurs in the central rainforest of Peru, with unexpected rains or prolonged periods of shade; also, large drying yard areas and personnel are needed to remove the layer of coffee, collect at sunset, cover the beans with plastic, spread them out the next day and control the drying, under the risk of loss of quality due to slowness in the process; as well as contamination with dust, fungi and the presence of animals that affect the safety of the dried beans (López and Chávez, 2018).

An alternative solution is to dry the coffee inside a solar dryer, which produces coffee beans with fewer defects (stains), ensuring greater safety and better sensory quality (Quintanar and Roa, 2017). In addition, this process contributes to using less space because they have shelves and drying beds (parihuelas), with plastic covers to avoid the collection of grains when it rains, reduce contamination due to the effect of trampling by operators or animals (Briceño-Martínez *et al*., 2020), obtaining an uneven drying if constant movements are not made to the mass of coffee and control of the high temperatures reached in the interior (Cruz *et al*., 2010).

The quality of dried parchment coffee depends on the variety grown, environmental conditions, agronomic practices, processing method, storage conditions (Tolessa *et al*., 2018), industrial processing and the final preparation of the beverage (Pabón and Osorio, 2019), interrelated characteristics that when modified can favor or deteriorate the sensory characteristics of the beverage (Ramos and Criollo, 2017). Therefore, the drying process of coffee beans is crucial to preserve the physical and sensory characteristics of the bean and the final product (Guevara-Sánchez *et al*., 2019).

Due to the lack of uniformity in the quality of the coffee lots dried on cement floors at the Cooperativa Agraria Cafetalera Perené (CAC Perené), which has 280 active members, for whom, at harvest time, the drying lines are insufficient and do not guarantee uniform quality or the safety of the beans, a solar greenhouse prototype was implemented with appropriate technology under different conditions for its proper operation and use. In this dryer, both the air extractor and the heaters work with photovoltaic cells, taking advantage of solar energy. This isolated system requires a power bank and is used where the electrical grid does not reach, which is currently expensive. The construction of this type of dryer had the primary purpose of serving all partners, seeking to improve the quality of coffee; due to the fact that, specialty coffees with high levels of cup requirement (> 84 points) are more required in the world market (Guevara-Sánchez *et al*., 2019). The use of solar energy accumulated in batteries was also prioritized to supply the extractors and heaters that operate at night, as indicated by the Sustainable Development Goals of the United Nations (United Nations, 2018). These variants were tested in the greenhouse type solar dryer, since there are no references of the adaptations in this type of dryer. The reduction in drying time contributes to a greater number of producers benefiting from this drying system, having more time available for other activities, as well as making their coffee lots more uniform in order to achieve better prices. In this context, the objective of this research was to determine the effect of three variants of a prototype greenhouse solar dryer on the physical, sensory, and microbiological quality of dried parchment coffee.

Materials and methods

Location and raw material

The study was carried out in the town of Marankiari, district of Perené, Province of Chanchamayo, Junín region, central Peru, at the CAC Perené. Catimor and Colombia varieties of coffee harvested between June and July 2021 were used.

Variants of the greenhouse-type solar dryer prototype

The technical characteristics of the prototype were designed by engineers contracted by CAC Perené as part of project PIMEN-10-P-040-144-15. The three variants in the drying prototype constituted the levels/factor under study, which are described below:

Prototype 1

Greenhouse type solar dryer with ventilators in the basal part (sliding doors) all covered with transparent and UV resistant plastic, oval shaped; dimensions 10 m wide, 20 m long and 6 m high; inside which were installed two-story table type parihuelas with dimensions of 1.50 m high, 4 m long, 1.50 m wide; 1 m separation height of the second floor, 50 cm separation of the second floor parihuelas; with structure of metal tubes of 3.54 cm in diameter.

Prototype 2

The first prototype was additionally fitted with a humid air extractor at the top of the dome; this equipment works with energy accumulated by the solar panel, which used an energy converter and a battery system for its storage.

Prototype 3

The second prototype was fitted with internal heating equipment such as incandescent lamps that operated at night with energy accumulated by the solar panels.

Methodology

The experiment was carried out according to the following stages:

Obtaining the oreado parchment coffee: The cherry coffee beans (470 kg) were pulped, fermented and washed, for their transfer they were filled in ventilated woven raffia sacks (280 kg). The coffee was transported from the plots in the different zones of the Perené district located at altitudes of 1000 to 1200 m.a.s.l. to the town of Marankiari where the prototype greenhouse-type solar dryer was installed. Travel time was approximately 6 hours.

Drying

It was carried out in the three variants of the prototype, the air-dried grains were placed in the drying racks inside the dryer (15 kg per treatment/repetition), data on time, weight, temperature and humidity were taken every 2 hours, turning the grains at the same time. The traditional sun drying (T0) also used dried coffee beans (15 kg per repetition), it was carried out on a cement floor with dimensions of 15 m x 10 m, which, because they were exposed to the environment, at night at 19 hours the beans were collected in mounds and covered with plastic, then at 07 hours the next day they were spread out again to continue drying, this was repeated until the desired humidity was reached; this process is the traditional way in which the members of the CAC Perené carried out the drying process.

Packaging

The dried parchment coffee beans that came from the variants and traditional sun drying were packaged in jute sacks, coded according to the treatments under study.

Quality control

Samples of 350 g of each treatment were taken and physical, sensory and microbiological evaluations performed in triplicate.

Analysis of fresh roasted coffee and dry parchment coffee

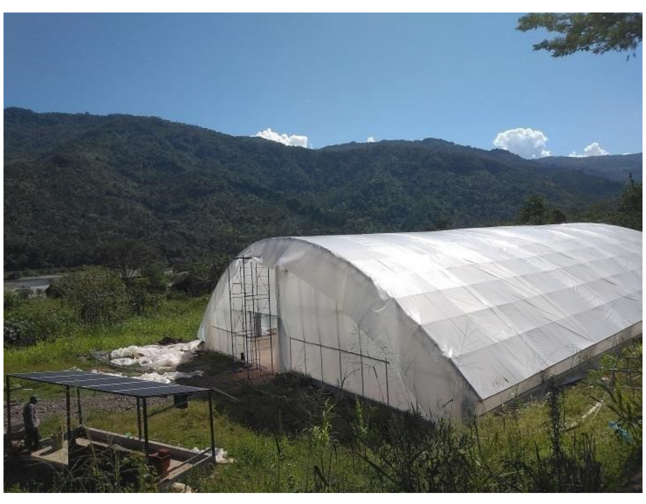
Moisture in the fresh coffee was determined by the thermogravimetric method and in the dry beans with a Wile Coffe® moisture meter with direct reading; acidity was determined by titration with NaOH 0.1 N in fresh coffee expressed as lactic acid and in dry coffee as malic acid, and pH with a digital potentiometer.

Controls during the process

The temperature and relative humidity data were measured during the drying time with six digital thermohygrometers, located four at the ends of the dryer and two in the middle part. The sun-drying temperature was determined with two digital thermohygrometers located on the coffee beans.

Analysis of dry parchment coffee

Number of defects and/or contaminants. The equivalences of defects described in the SCA (Specialty Coffee Association) manual were used, which differentiates between category 1 or primary defects and category 2 or secondary defects. Each type of defect was counted individually; according to the manual, if two simultaneous defects



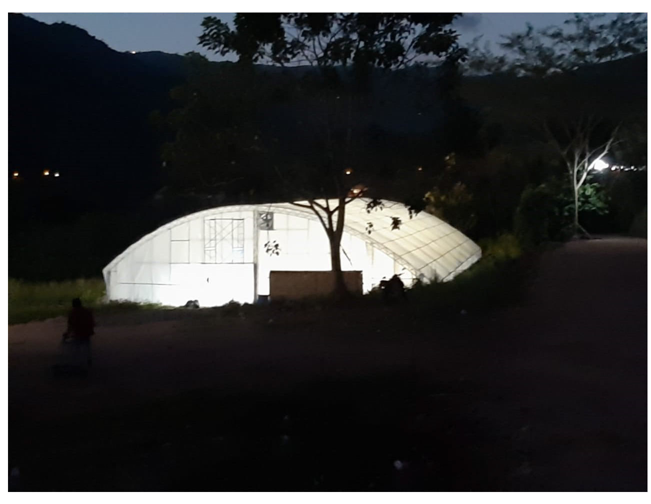


Figure 1. Day and night view of the prototype used in the research.

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are found, the one with the greatest impact is taken into account; bean malformations are not defects (SCA, 2019).

Yield factor

This value was obtained by dividing the weight of gold coffee by the weight of dry parchment coffee, adjusted to a reference humidity percentage (12 %).

Sensory analysis

It was performed with a certified Q grader cupper following the preparation and analysis protocols according to the SCA standard (2003), with three repetitions per sample, the attributes evaluated were: Fragrance/Aroma, Flavor, Residual Flavor, Acidity, Body, Balance, Uniformity, Clean Cup, Sweetness and Taster Score; the final result was expressed on a scale of 0 to 100 points; with the range of 90 to 100 being considered exceptional, 85 to 89.9 excellent, 80 to 84.9 very good with description of special, and < to 80 below special quality (SCA, 2015).

Microbiological analysis

In addition to mold counts, yeasts, *Escherichia coli* and mycotoxins (Ochratoxin A) were also determined.

Statistical analysis

With the results of the physical and sensory characteristics, analysis of variance was performed in a complete randomized design with three replications. In the variables that presented significant differences, the Tukey test was performed at 5 %.

Results and discussion

Physicochemical characteristics of fresh and dry coffee bean

The humidity of freshly washed coffee is 53 %, which is reduced during air-drying to 48.8 % (surface drying of the parchment). The humidity of dried beans does not show significant differences, the overall average being 11.72 % (table 1), an acceptable average for storing the product, preserving its quality (Prada *et al*., 2019) and stability (Osorio *et al*., 2022). According to Gallego and Rodriguez (2021), dry coffee beans should have a humidity between 10 and 12 %, to be stored for up to 10 months. The acidity and pH of the beans do not show significant differences either, with averages similar to those reported by (Camargo Caysahuana and Contreras Rodríguez, 2020). In this regard, López *et al*. (2015) observed a decrease in pH during fermentation, which can influence coffee quality, therefore, (Juárez *et al*., 2021) highlights the importance of fermentation control in the production of high quality coffee.

These studies highlight the importance of monitoring and controlling the pH and acidity of coffee during the fermentation and drying processes.

Controls of time, temperature and humidity during drying process

Table 2 shows that the drying time of parchment coffee beans in prototype 1 (greenhouse type solar dryer) was 112 hours (approx. 5 days), in prototype 2 with humid air extractor it was 58 hours (approx. 2 ½ days), in prototype 3 with humid air extractor and heaters during the night it was 54 hours (approx. 2 ½ days) and in the traditional drying it was 124 hours, considering that only 12 hours were dried, from 7:00 am to 7:00 pm which is equivalent to 9 days. 2 days and ¼) and in the traditional drying was 124 hours, considering that only 12 hours were dried, from 7:00 am to 7:00 pm which is equivalent to 9 days, evidencing that the drying time is reduced when the air extractor and incandescent lamps work in prototype 3; the traditional drying time is similar to that performed in the valley of Alto Mayo, San Martin region in Peru at an altitude of 873 m.a.s.l. (Guevara-Sánchez *et al*, 2019). Inside the dryer temperatures are higher and are possible to control as well as relative humidities when using the air extractor, in this regard (Prada *et al*., 2019) and (Quintanar and Roa, 2017) found that solar dryers with continuous air flow systems, powered by photovoltaic energy, are effective in reducing coffee drying time, with better control of relative humidity and temperature. In the present research, using the variants of the prototype, shorter drying times were achieved while preserving the intensity of the bean's acidity and consequently its cup quality.

Defects number in dried grains

No primary defects were found in any of the prototype variants, but in traditional drying, partially sour kernels (2 defects), which according to SCA (2019) occurs after harvesting and foreign matter (stones and sticks, 2 defects) due to drying in yard. Secondary defects were only found in prototype 1 (2 defects: floating kernels and shell kernels), while in traditional drying 13 defects: floating beans, shell beans and split beans due to mechanical damage caused by the use of wooden trackers used in the coffee storage operations at night; demonstrating that with the prototypes the number of defects was reduced improving the quality of the coffee, in this regard, SCA (2015) points out that special coffees in green gold bean meets

Table 1. Physicochemical analysis of wet and dry parchment coffee beans.

Component	Fresh roasted coffee	Dry coffee			
		Prototype 1	Prototype 2	Prototype 3	Traditional drying
Humidity (%)	48.80 ± 0.35	11.84 ± 0.14^{a}	11.79 ± 0.10^{a}	11.69 ± 0.11^{a}	11.60 ± 0.10^{a}
Acidity (%)	0.20* ± 0.03	1.26** ± 0.06^{a}	1.24** ± 0.14^{a}	1.19** ± 0.09^{a}	1.29** ± 0.06^{a}
pH	4.50 ± 0.18	6.19 ± 0.19^{a}	6.21 ± 0.19^{a}	6.25 ± 0.14^{a}	5.98 ± 0.10^{a}

Note: *Expressed in lactic acid, **Expressed in malic acid.

Table 2. Time, temperature and relative humidity during drying process.

Type of dryer	Drying time (h)	Drying condition	
		T (°C)	HR (%)
Prototype 1	112.05 ± 0.94^{d}	58.04 ± 0.96^{c}	67.03 ± 1.67^{c}
Prototype 2	58.04 ± 1.05^{b}	50.04 ± 1.29^{b}	63.04 ± 0.51^{b}
Prototype 3	54.07 ± 0.60^{a}	50.00 ± 0.64^{b}	60.03 ± 1.17^{a}
Traditional drying	124.00 ± 1.20^{c}	40.05 ± 0.92^{a}	75.03 ± 1.62^{d}

Different letters indicate significant differences obtained by Tukey's mean comparison test (P≤0.05).

exceptional physical characteristics in terms of granulometry and reduced presence of defects, and to be considered green gold coffee Special Grade must have maximum 5 secondary defects and no defect category 1 (primary) in 350 g; the results obtained show that in the variants of the greenhouse type dryer all the beans are of Special Grade, which is not the case with the traditionally dried beans, which presented primary and secondary defects; therefore, the use of the variants of the dryer allowed a better control of the drying process avoiding the majority of defects.

Parchment to gold yield

In Table 3, it can be seen that there is a significant difference in the yield of gold coffee, with prototype 3 having the best yield factor 0.833 and a yield in exportable gold coffee of 83.24 %; in this regard, when a coffee has more than 74 % of healthy kernel, coffee growers receive an incentive for quality (Gamboa *et al*., 2015), therefore, with the use of the solar dryer prototype in all variants it is possible to obtain a better yield and beans of better physical quality with fewer defects.

Sensory analysis of dry beans

Table 4 shows that the best results were obtained in prototype 3, followed by prototype 2, with no significant differences between them; in prototype 1 and in the traditional drying process lower scores were obtained; in the dried coffees in the prototypes sweet notes, citric acidity, smooth body, smooth aftertaste, clean coffee were found; while in the traditional drying process notes of sweet chocolate, light acidity, light body, astringency and bitter aftertaste were found. In the prototypes the final scores are above 82 points, which according to the classification (SCA, 2015) from 80 to 84.99 corresponds to a Very Good - Specialty coffee. Therefore, in the evaluated prototypes, in addition to preserving the sensory quality, it reduced the drying time, protecting the beans from external agents and with less presence of primary defects, demonstrating that with prototype 3 beans with optimal physical and sensory quality are obtained (84.25 points) for marketing how specialty coffee and achieve better prices; similar to that achieved by Juarez *et al*. (2021) in specialty coffee with 84 points, and Gallego and Rodriguez (2021) in coffee with special quality with 81.3 points.

Microbiological analysis in dried parchment coffee

In addition to the determination of molds in coffee beans referred to by INACAL (2021), in order to verify the safety conditions of the beans, the numbering of yeasts and *Escherichia coli* has also been determined; in all the variants of the prototype, the values determined were below this limit; but in the case of coffee obtained by traditional drying, when the presence of molds was found, the determination of Ochratoxin A was carried out, whose maximum permissible level is 10 $ng.g^{-1}$ (ppb) (NTP 209.320, 2021); in the investigation, the results were not detectable (N.D.), therefore, even when molds were found in the coffee beans dried in the sun on a cement floor, the presence of Ochratoxin A has not been detected (table 5).

Table 3. Parchment to gold coffee yield and yield factor (YF).

Type of dryer	Parchment weight	Gold coffee (exportable)		YF
	g	%	Weight (g)	
Prototype 1	350	80.20	$280.70^{b} \pm 1.58$	0.802
Prototype 2	350	80.56	$281.97^{b} \pm 4.23$	0.806
Prototype 3	350	83.24	$291.33^{a} \pm 1.50$	0.833
Traditional drying	350	78.72	$275.50^{b} \pm 3.51$	0.787

Note: YF is a coefficient that multiplied by the initial parchment weight (adjusted to a reference percentage of humidity (12 %) gives the weight in gold coffee.

Table 4. Sensory profile of green gold coffee beans.

Attribute	P1	P2	P3	T0
Fragrance/ Aroma	7.50	7.75	7.75	6.00
Flavor	7.50	7.75	7.75	7.00
Residual Flavor	7.25	7.75	7.75	7.25
Acidity	7.50	7.75	7.75	7.25
Body	7.25	7.50	8.00	7.25
Balance	7.50	7.50	7.75	7.50
Uniformity	10.00	10.00	10.00	10.00
Clean Cup	10.00	10.00	10.00	10.00
Sweetness	10.00	10.00	10.00	10.00
Tasting Point	7.50	7.50	7.50	7.25
Averages	**$82.00^{c} \pm 0.25$**	**$83.50^{a,b} \pm 0.25$**	**$84.25^{a} \pm 0.25$**	**$79.50^{d} \pm 0.50$**

Different letters indicate significant differences obtained by Tukey's mean comparison test (P≤0.05).

Table 5. Microbiological results of coffee beans.

Type of dryer	Molds UFC.g^{-1}	Yeast UFC.g^{-1}	*E. coli* NMP.g^{-1}	Ochratoxin A µg.kg^{-1} (*)
Prototype 1	< 10	< 10	< 3	--
Prototype 2	< 10	< 10	< 3	--
Prototype 3	< 10	< 10	< 3	--
Traditional drying	25x10^{2}	< 10	< 3	N.D.

Note: The determination of ochratoxin A was performed only in coffee from traditional drying because the presence of mold was detected.

Conclusions

In the greenhouse type solar dryer with air extractor and heaters (P3) the drying time of coffee was reduced from 9 days to 2 ¼ days, achieving dry parchment coffee beans, without primary defects, with a higher percentage of exportable coffee (83.24 %), a sensory profile of 84.25 points and with better safety than in traditional drying; in addition, it has advantages over traditional drying and similar solar dryers, because it works day and night using renewable energy generated by solar panels; and by drying a greater quantity in a smaller space it benefits a greater number of members of the CAC Perené in obtaining coffee with good cup quality and free of contaminants.

Literature cited

Briceño-Martínez, B., Castillo-Calderón, J., Carrión-Jaura, R., & Díaz-Sinche, D. (2020). Proposal for implantation of coffee drying greenhouse with parabolic cover and adapted modular structure. *Ingenius. Revista de Ciencia y Tecnología*, (24), 36-48. https://doi.org/10.17163/ings.n24.2020.04

Camargo Caysahuana, A. y Contreras Rodríguez, J. H. (2020). Influencia del proceso de fermentación del café (*Coffea arabica*) en la durabilidad del concreto en laboratorio, Satipo – 2018. *Prospectiva Universitaria, Revista de la UNCP*. *17*(1), 31-40. https://doi.org/10.26490/uncp.prospectivauniversitaria.2020.17.1395

Cruz, D., López de León, E., Pascual, L. F. y Battaglia, M. (2010). Guía técnica de construcción y funcionamiento de secadoras solares tipo domo. *Journal of Agriculture and Environment for International Development (JAEID), 104*(3/4), 125-138. https://www.originicaffe.it/doc/15-84-1-pb.pdf

Gallego, C. P., & Rodríguez, N. (2021). Identificación de algunas variables fisicoquímicas y microbiológicas asociadas con el defecto reposo en el café. *Revista Cenicafé, 72*(1), e72105. https://doi.org/10.38141/10778/72105

Gamboa, P. Y., Mosquera, S. A., & Paz, I. E. (2015). Characterization of especial coffee (*Coffea arabica*) in chachagüí (Nariño, Colombia). *Revista Lasallista de Investigación, 12*(1), 90-98. https://goo.su/v4WR1Is

Guevara-Sánchez, M., Bernales del Aguila, C. I., Saavedra-Ramírez, J., & Owaki-López, J. J. (2019). Effect of altitude on coffee (*Coffea arabica* L.) quality: comparison between mechanical and traditional drying. *Scientia Agropecuaria, 10*(4), 505-510. doi:10.17268/sci.agropecu.2019.04.07

INACAL (Instituto Nacional de Calidad). (2021). *Café tostado en grano o molido. Requisitos*. NTP 209.028:2015. GIP 16. Lima Perú. https://goo.su/LKiFrv6

Juárez, T., Maldonado, Y. I., González, R., Ramírez, M. O., Álvarez, P., y Salazar, R. (2021). Caracterización fisicoquímica y sensorial de café de la montaña de Guerrero. *Revista mexicana de ciencias agrícolas, 12*(6), 1057-1069. https://doi.org/10.29312/remexca.v12i6.2773

López, I. y Chávez, E. (2018). Eficacia de secador solar tipo túnel con cacao (*Theobroma Cacao* L.) en Tabasco. *Revista mexicana de ciencias agrícolas, 9*(SPE21), 4395-4405. doi:10.29312/remexca.v0i21.1528

López, C. F., Rojas, P. A., Montaña, L. O., Tovar, E. S., Rojas, Y., Arcos, C. A., Ordoñez, C. M. y Vega, G. A. (2015). Estudio de algunas variables en el proceso de fermentación de café y su relación con la calidad de taza en el sur de Colombia. *Agroecología: ciencia y tecnología. 3*(1): 7-12. https://goo.su/eczuSbB

Naciones Unidas. (2018). *La Agenda 2030 y los Objetivos de Desarrollo Sostenible: una oportunidad para América Latina y el Caribe*. (LC/G.2681-P/Rev.3), Santiago.

NTP (Norma técnica Peruana). 209.320:2021. Café verde. Determinacion de ocratoxina A. 1ra. Edicion. https://goo.su/wz9UD0c

Osorio, V., Pabón, J., Shuler, J., y Fernández-Alduenda, M. R. (2022). Efecto de la combinación de procesos de secado en la calidad del café natural obtenido vía seca. *Revista Cenicafé, 73*(1), e73101. doi: https://doi.org/10.38141/10778/73101

Pabón, J. P. y Osorio, V. (2019). Factores e indicadores de la calidad física, sensorial y química del café. *Cenicafé, 7*: 162-187. doi: https://doi.org/10.38141/10791/0005_7

Prada, Á., Vela, C. P., Bardález, G., & Saavedra, J. (2019). Effectiveness of a coffee drying process using solar dryers with a continuous air flow system powered by photovoltaic energy, in the San Martín región, Perú. *Información tecnológica, 30*(6), 85-92. doi: http://dx.doi.org/10.4067/S0718-07642019000600085

Quintanar, J. & Roa, R. (2017). Evaluación térmica y financiera del proceso de secado de grano de café en un secador solar activo tipo invernadero. *Revista mexicana de ciencias agrícolas, 8*(2), 321-331. doi: https://doi.org/10.29312/remexca.v8i2.53

Ramos, L. J., & Criollo, H. (2017). Calidad física y sensorial de *Coffea arabica* L. variedad Colombia, perfil Nespresso AAA, en la Unión Nariño. *Revista de Ciencias Agrícolas, 34*(2), 83-97. doi: http://dx.doi.org/10.22267/rcia.173402.74.

SCA (Specialty Coffee Association). (2019). El café arábica lavado. Guía de defectos del café verde. Manual. California, Estados Unidos. https://goo.su/Y9S5

SCAN. (2015). Guía de factores que inciden en la calidad del café: Una alternativa para hacer el cafetal sostenible.

SCA (2003). Protocols & Best Practices. https://sca.coffee/research/protocols-best-practices.

Torres-Valenzuela, L. S., Martínez, K. G., Serna-Jiménez, J. A., & Hernández, M. C. (2019). Drying of coffee pulp: Process parameters, mathematical model and its effect over physicochemical properties. *Información Tecnológica 30*(2), 189-200. doi: http://dx.doi.org/10.4067/S0718-07642019000200189

Tolessa, K., Duchateau, L., & Boeckx, P. (2018). Analysis of coffee quality along the coffee value chain in Jimma zone, Ethiopia. *African Journal of Agricultural Research, 13*(29), 1468-1475. doi: https://doi.org/10.5897/AJAR2018.13118