Original Article

Extraction By Physicochemical Methods Of Tara (Caesalpinia Spinosa) And Its Application In Sustainable Industry

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DOI: 10.47750/pnr.2023.14.S02.24

Abstract

Tannins present in several plants are a valuable resource for various industries, being Tara one of the most important raw materials of these compounds, that is why the extraction process (at the laboratory level) of this plant was analyzed with the use of different solvents. First, samples of Tara powder (or flour) distributed by the Association of Farmers of Chimborazo were analyzed, and then the effect of the use of different organic solvents (ethanol, isopropanol, acetone and hexane) on the extraction yield with the Soxhlet technique in this powder was evaluated. In parallel, a hydroalcoholic extraction was performed under different operating conditions (ethanol content in the water-ethanol mixture equal to 50; 75 and 96% and different solid:liquid ratios equal to 1:5, 1:10 and 1:15) in search of optimizing the extraction process. It was determined that the best extraction conditions of Tara are produced with a hydroalcoholic extraction with a 75% ethanol content and a ratio equal to 1:10 solid:liquid at 40°C for 3 hours, reporting an average yield equal to 14.26% of the extract. The results obtained can provide the scientific basis for the design of industrial extraction processes and the subsequent use of Tara in the province of Chimborazo, providing benefits of various kinds to the producers of this plant in the region concerned.

Keywords Tara, *Caesalpinia Spinosa*, extraction, tannins, solvents, sustainability, physicochemical, physicochemical.

RESUMEN

Los taninos presentes en diversas plantas constituyen un preciado recurso para diversas industrias, siendo la Tara una de las materias primas más importantes de dichos compuestos, es por ello por lo cual se analizó el proceso de extracción (a nivel de laboratorio) de dicha planta con la utilización de diferentes solventes. En primer lugar, se analizaron muestras de polvo (o harina) de Tara distribuida por la Asociación de Agricultores de Chimborazo, posteriormente se evaluó el efecto que ejerce la utilización de diferentes solventes orgánicos (etanol, isopropanol, acetona y hexano) sobre el rendimiento de la extracción con la técnica de Soxhlet en dicho polvo. De forma paralela, se procedió a la realización de una extracción hidroalcohólica bajo diferentes condiciones de operación (contenido del etanol en la mezcla de agua-etanol igual a: 50; 75 y 96% y diferentes proporciones sólido:líquido iguales a: 1:5, 1:10 y 1:15) en búsqueda de optimizar el proceso de extracción. Se determinó que las mejores condiciones de extracción de la Tara se producen con una extracción hidroalcohólica con un contenido del 75% de etanol y una relación igual a

1:10 sólido: líquido a 40°C por 3 horas, reportándose un rendimiento promedio igual a 14.26% de extracto. Los resultados obtenidos pueden brindar la base científica para el diseño de procesos industriales de extracción y el subsecuente aprovechamiento de la Tara en la provincia del Chimborazo, brindando beneficios de diversos indoles a los productores de dicha planta en la región en mención.
Palabras claves
Tara, *Caesalpinia spinosa*, extracción, taninos, solventes, sostenibilidad, fisicoquímico

1. Introduction

This study analyzed the extraction of Tara (*Caesalpinia Spinosa*), to determine, at laboratory scale, the conditions of the extraction process that generate the highest yield in obtaining extracts from samples of Tara powder marketed in Ecuador.

Tara is considered a small leguminous tree belonging to the *Caesalpinaceae* family, native to the Cordillera of Bolivia, Peru (the largest producer and exporter of Tara) and northern Chile. This tree can also be found in countries such as Ecuador, Colombia, Venezuela and even Cuba, and recently, it has been planted in Morocco and East Africa (Seabra, 2010; Aybar & Zavala, 2016).

Tara (commonly known as taya, guarango, cuica, serrano, divi de tierra fría or dividi de los andes or vinillo) has evergreen leaves and grows at elevations between 0 and 3000 meters above sea level, can tolerate dry climates and poor soils, including those with lots of sand and rocks. It has a stem whose height varies between 3 to 5 meters, with grayish bark and produces orange pods indehiscent, oblong and flat containing four to seven rounded seeds which are the main usable part of the plant, for its high percentage of tannins (mainly *gallotannins*), presenting content of between 40 to 60% dry and even more in some cases, being gallic acid the main component, which is present in concentrations above 53% in aqueous extracts of Tara (Li, *et al*., 2016; ASOCAM, 2022; Cuyan, 2019; Araujo & Salas, 2009; Ballesteros, *et al*., 2021, Garro, *et al*., 1997; Chambi, *et al*., 2013; Wischer, *et al*., 2013; De la Cruz, 2004; Callohuari, *et al*., 2017).

Similar to the other species belonging to the *Caesalpineae*, Tara has a great value for the industry due to its high content of tannins (which are considered an important industrial resource, since its annual production amounts up to 2,000,000 tons per year). Tara is used in food production and medicine, acting as a raw material rich in tannins, gums, hydrocolloids and gallic acid, among others. Tara represents the second most important raw material in processes that require tannins, which are non-toxic organic compounds, specifically polyphenols that are soluble in water, whose molecular weight is relatively high (between 500 and 3000 molecular weight units), and generate their own phenolic reactions and have special characteristics, for example, generate the precipitation of alkaloids and some proteins such as gelatin. Tara tannins are hydrolyzable and are formed by basic units of gallic acid linked by ester bonds to quinic acid. Tara has the most important application in tanning due to its tannin content since it can transform the molecules of the skin obtained from animals (which is perishable) into the leather (which is a non-perishable material) through the formation of hydrogen bonds between the hydroxyl phenolic groups of the tannins and the peptide groups of the amorphous regions of collagen. Vegetable tanning agents represent some of the oldest materials used in leather production. Currently, non-natural substances are still used for leather production, such as chromium salts, which represent 70% percent of the leather industry around the world and are responsible for the contamination of the leather industry, a fact that provides a very large market for tannins obtained from Tara, making it competitive with tannins obtained from other plants such as pine, acacias and chestnut (De la Cruz, 2004; Isaza, 2007; Avilés *et al*., 2010; Li *et al*., 2016; Marín, 2022; Callohuari *et al*., 2017, Kusuma *et al*., 2022; Gaidau *et al*., 2014; Bellotti *et al*., 2012; Hrůzová *et al*., 2021).

Another important application of Tara is represented by the obtaining of gallic acid from the hydrolysis of tannins. This compound is used in the oil industry as an antioxidant agent and in general in the food industry, as a bleaching agent in the production of beer or the preparation of fruit drinks. In the photographic and ink production industry it is used to form gallates that react and form the dark blue color of the products. It is not only tannins that can be used in Tara. Several studies analyze the use of the gum and other constituents of the Tara pod, for example, the gum obtained from the pod (with different means to those studied in this research) can be used as a food additive without presenting any toxicity and can even be used in the pharmaceutical industry, for example, as an encapsulating material for vitamin D (Borzelleca *et al*., 1993; De la Cruz, 2004).

Tara has also been empirically applied in medical treatments. This plant has been used pharmacologically even since pre-Hispanic times, for being a plant rich in tannins. In ancestral medicine, Tara has been used for its antidysenteric, astringent and healing properties. The content of gums, tannins and flavonoids (secondary metabolites) allows it to be used today in medicine and as a photoprotector against oxidative damage. The tannic acids that can be obtained from Tara extracts have characteristics that can be used in medical treatments and disease prevention. For example, it acts as an inhibitor of tumor growth induced by chemical agents and also acts as inhibitor of carcinogenesis caused by the action of ultraviolet light (which has been proven in mice in laboratory tests). Gallic acid, which can be obtained from Tara extracts, has been shown to possess antioxidant, anti-inflammatory, anti-allergic, anti-mutagenic and anti-cancer capabilities, acting also as an agent for the reduction of cancer cell proliferation in cervical cancer, leukemia and melanoma and can be applied as an adjuvant along with conventional chemotherapy treatment to treat tumors with MDR (multi-drug resistant) phenotype or with high frequency of CSC (cancer stem cells). Several applications for Tara tannins in wastewater treatment have been studied, verifying that these extracts can remove cationic dyes through their application in the form of biopolymers (Sandoval *et al*., 2016; Sánchez *et al*., 2011; Nuñez *et al*., 2016; Rojas *et al*., 2011; Nuñez & Quispe, 2015; De la Cruz, 2004; Santos *et al*., 2021).

The processes that allow the recovery of bioactive compounds in plant raw materials represent a key step in their utilization, among which extraction is one of the most important steps. Laboratory techniques for extraction in plants range from conventional methods (using solvents or mechanical action, such as maceration, percolation, infusion, and entrainment, among others) to more advanced techniques (such as extraction assisted by microwaves, ultrasound or through supercritical substances, among others). In solvent extraction, a wide range of solvents has been used in the processing of Tara, because of the great variety of polarities and physical properties of the compounds of interest to be extracted from the plant, which makes it impossible to use a single solvent. Both the solvent and the applied technique influence the extraction product; however, the type of solvent is the parameter that most influences the extraction process yield, being organic solvents (such as methanol, ethanol, chloroform, acetone, among others) the most used, which is why the correct selection of the solvent and the extraction technique based on the extracts of interest in the plant to be obtained is very important. The extraction of tannins is still a challenge, due to their heterogeneous nature. Such extraction is not performed under a single protocol, that is, the available techniques for the extraction of tannins are very varied. For the extraction of phenolic compounds (such as tannins or polyphenols), extraction with polar solvents must be applied. In general, the extraction of tannins is carried out with water at a high temperature or with water combined with other solvents directly from the plant material of interest (bark, wood, stem, leaves, fruits, among others). The solvents commonly used in the extraction of tannins are acetone, Di isopropyl ether, ethyl acetate, ethyl ether, methanol, ethanol, sodium sulfite and sodium hydroxide with or without water. Hexane is also used in the extraction of tannins; however, it is not a very common method. The most common technique used in the industry and at the laboratory scale for the extraction of tannins uses only water at high temperatures, due to its simplicity and economy. Pressure, temperature, time and particle size of the plant material to be treated also play a very important role. At higher pressures and temperatures, the extraction yield is higher, while at smaller particle sizes the extraction is higher because the solvent can penetrate more easily into the particle, which reduces the time needed for extraction. The efficiency of the extraction and the quality of the tannins obtained depends on the duration of the extraction stage; in other words, the longer the duration of the extraction, the higher the extraction yield, since the structure of the plant material decomposes as it is exposed to the solvents and a greater quantity of tannins is released; however, it should be considered that the quality of the extracts can deteriorate as time passes because they are in contact with the solvent. The proportion between the plant material (solid) and the solvent also represents an important factor in the extraction, with higher proportions of solvent/solid improving the performance of the process since this proportion improves the contact between the solvent and the particle of the solid. For this reason, continuous mixing (agitation) also favors extraction. Finally, in the extraction process, the number of impurities present in the product will depend on the operation parameters, which is why the operating conditions in the extraction must be precisely controlled (Kumar *et al*., 2021; Choudhary *et al*., 2021; Dirar *et al*., 2019; Das *et al*., 2020).

The main objective sought to be achieved with the present research work was to analyze the process of obtaining the extracts of tara powder by applying different extraction methods. It was also sought to

determine the effect of the solvent on the extraction process, in this case, ethanol, isopropanol, acetone and hexane were used as solvents under a Soxhlet extraction.
The importance of this research project derives from the fact that the results of the experimentation will allow the projection of industrial applications to the extracts generated, specifically, within the province of Chimborazo in Ecuador, since Tara is available in this region, however, an industrial application has not been generated to enhance its production and use on a sufficient scale to provide economic and social benefits to potential beneficiaries of the province concerned. At present, the Tara produced in the province of Chimborazo is marketed to Italy and Peru at a low price.
Within the experimental work, the extraction of tara powder was carried out using different solvents and techniques to obtain products that present an added value, which can be used later in different industrial applications in Ecuador. After determining the appropriate solvent for the extraction, which presented the highest yield, the process was optimized through the use of a simple stirred extraction reactor. Currently, there is a great interest in the study of extraction techniques for tannins from biomass, since industries require such extracts with different purities, structures and chemical compositions for each of the applications of these compounds. However, this process has a disadvantage, since the extract obtained contains many other components of the treated plant material, which affects the quality of the extract, which is why other processes for obtaining tannins should be studied (Hrůzová *et al*., 2021).

2. Materials and Methods

2.1. Materials

The Tara powder analyzed was provided by the Association of Farmers of Chimborazo, having taken a sample of the Tara product marketed in Ecuador, which is sold in 10 kg bags. The Tara powder was stored in a dark room in the same bag in the laboratory under atmospheric conditions of temperature and pressure (15°C and 0.90 atm).

2.2. Reagents used

The reagents used in the Tara extraction were the following: ethanol (purity: 90%); distilled water; ethyl acetate (purity: 80%); n-hexane (purity: 85%); acetone (purity: 85%); isopropanol (purity: 70%).

2.3. Methods

2.3.1. Determination of moisture content

The moisture content of the commercial Tara powder sample was determined. For this purpose, the technique of mass difference titration of a powder sample before and after drying in a muffle at 120°C was applied. The same procedure was repeated three times. The following equation was used to calculate the moisture content of the sample:

$$MC = \frac{m_1 - m_2}{m_1 - m_0} * 100$$

Where:

- m_0: Mass of the sample container before drying, g
- m_1: Mass of sample plus container before drying, g
- m_2: Mass of sample plus container after drying, g
- MC: Moisture content, %

2.3.2. Density measurement

The evaluation of the density of the Tara powder was carried out in triplicate for subsequent calculations, using a 15m pycnometer. The following equation was used for the density calculation:

$$\rho_t = \frac{m_s}{V_p}$$

Where:

- ρ_t: Tara powder density, g/ml

- m_s: Tara powder mass, g
- V_p: Pycnometer volume, ml

2.4. Soxhlet extraction

A laboratory Soxhlet apparatus was used for solvent extraction of Tara powder, applying four solvents of different polarities. Ethanol 96%, acetone, isopropanol and n-hexane were used. Three parallel measurements were performed with the four solvents. For the Soxhlet extraction, the following procedure was followed:

- Twenty grams of tare powder were weighed in a paper extraction thimble using the analytical balance. Three parallel measurements were performed. Absorbent cotton was placed over the Tara powder to avoid the loss of particles during extraction.
- The paper thimble with the sample was placed in the Soxhlet apparatus by attaching it to the round bottom flask containing an amount of solvent based on the previously established solvent/powder (or solid) ratio (which is described later).
- The Soxhlet apparatus was assembled and cooling water was introduced into the condenser and, once the water flow was verified, the heat sources were turned on. The flasks were immersed in a silicone oil bath, which was heated by an electrical heating surface. The temperature of the oil bath was set above the boiling point of the applied solvent.
- The extraction was carried out until the solvent around the Tara powder (in the Soxhlet apparatus) became transparent. Once the extraction was finished, the equipment was disassembled. The wet extracted plant material together with the paper extraction thimble was placed in a drying flask. The solvent enriched with the extract was retained in the round bottom flask.
- Having obtained the crude extract, the solvent was evaporated using a rotary vacuum evaporator, whereby the solvent could be evaporated at low temperatures. After evaporation, the flasks were reweighed on the analytical balance, so that the mass of the extract could be calculated by the difference in weights. The extracts were scraped from the flask and collected in bottles suitable for containing and preserving such substances, which were labeled and kept cold.
- The extraction yield was calculated from the weight of the plant material and the weight of the extract by applying the following equation:

$$Extraction\ Performance = \frac{me}{m_p} * 100$$

Where:

- m_p: Mass of dry plant material, g
- me: Mass of extract obtained (without solvent), g

2.5. Hydroalcoholic extraction

In addition to the process described above, Tara was extracted through a hydroalcoholic solvent technique, to contrast the values obtained in the previous extraction stage with the different solvents. For the hydroalcoholic extraction process, extraction equipment with the agitation was used. Two different solvent formulations were used: 50-50% (mass/mass), 25-75% (mass/mass) ethanol-water and only ethanol (96%) in the solvent formulation. Each stage of the extraction lasted 3 hours at 40 °C, for which an electric reverberator was used. The mass ratio between the powder and Tara and the solvent was established in different proportions, as described later. The extraction was carried out under continuous stirring conditions with a speed between 40-50 rpm. In all tests, three parallel measurements were carried out, using the following procedure:

- Approximately 200 grams of the Tara plant material were weighed and the ethanol-water mixture was prepared using absolute ethanol and distilled water.
- The flask containing the Tara powder and the solvent was placed in the stirrer at a stirring speed of 40 rpm, which generated that the extraction is performed under homogeneous mixing conditions. The temperature was also adjusted to 40ºC, for which a thermometer was used.

- After the extraction period, the sample was removed from the equipment and the product was vacuum filtered using a filter paper and the filtrate product was placed in a rotary evaporator to purify the extract. In the separation of the water-ethanol mixture (solvent) and the extract, the conditions were set at 60°C and a vacuum of 82 mPa. After a couple of hours at the rotary evaporator. It could be observed that there was a viscous solid in the flask. After the total removal of the liquid solvent, it was necessary to apply a full vacuum for about 30 minutes to remove all solvent residues in the sample.
- After the flask with the extract inside was cooled, the weight of the extract was titrated to calculate the mass of the extract and the extraction yield. The extraction product was collected from the flask and placed in a bottle suitable to contain the extraction product. The bottle was stored in a refrigerator for further analysis. The extraction yield was calculated based on the previous description.

2.5.3. Optimization of the hydroalcoholic extraction of Tara

Additional extractions were carried out to achieve optimization of the hydroalcoholic extraction of the tare using the stirring equipment and with 50, 75 and 96% ethanol-water ratios as solvents in different solid to liquid ratios: 1:5, 1:10 and 1:15 mass to volume at 40 °C, with a shorter extraction time than described in the previous section. The extraction took approximately 3 hours per sample. Each extraction was performed based on the procedures described in the previous sections. To evaluate the effect of the ethanol-to-water ratio in the solvent formulation and the solid-to-liquid ratio on the extraction yield, a factorial 32 experimental design was established with three repeated measurements in the center of the design. The independent variables were the ethanol-water formulations in the solvent (50,75 and 96%) and the solid-to-liquid ratios (1:5, 1:10 and 1.15 mass ratio of Tara powder/solvent volume), while the total extraction yield was set as the dependent variable (response variable). The summary of the experiment can be verified in Table 1.

Table 1: Summary of experimental design.

Ethanol concentration, %	Ratio, mass of sample:volume of solvent	Sample number
96	1:5	1
96	1:10	2
96	1:15	3
75	1:5	4
75	1:10	5
75	1:15	6
75	1:10	7
75	1:10	8
50	1:5	9
50	1:10	10
50	1:15	11

3. Results and Discussion

3.1. Moisture content of the simples

Table 2 shows the results of the moisture content of three samples (ground Tara material or Tara powder) taken in parallel. The table also shows the total mass of the plant material obtained after the grinding process. The moisture contents of the samples were obtained using the procedures and equations described in the previous section, resulting in an average of 13.42±2.71% among the 3 samples.

Table 2. Results were obtained from the analysis of the moisture content of the different samples of tara powder.

Particle size, mm	Total mass of plant material, g	Sample	Vessel mass, g	Mass of container + sample, g	Dough after drying, g	Moisture content, g	Average moisture content, %	Average dry content, %
4	2000	Sample 1	338.856	345.903	296.034	16.456±2.71	13.42±2.71	86.58±2.71
		Sample 3	337.504	346.059	270.141	11.27±2.71		
		Sample 2	47.481	485.491	389.515	12.52±2.71		

The average dry matter content of the tara powder was 86.58 ± 2.71 %, which shows that the tara contained almost 14 % moisture.

3.2. Tara powder density

Table 3 shows the density results of the three parallel samples (ground Tara material) that were analyzed during the investigation. The table also shows the total mass of the plant material obtained after the grinding process. The moisture content of the samples was on average equal to 1.13±2.71 g/l in the 3 samples.

Table 3: Results obtained in the analysis of the moisture content of the different Tara powder samples.

Pycnometer volume, ml	Sample	Pycnometer mass, g	Pycnometer mass + sample, g	Tara powder density, g/L	Average density, g/L
15	Sample 1	10.25	16.85	1.12	1.13±0.03
	Sample 2	10.25	17.4	1.16	
	Sample 3	10.25	16.5	1.11	

3.3. Extraction process performance

Table 4 and Figure 1 show the results of the evaluation of the extraction process to which the Tara powder was subjected.

Table 4: Results obtained in the analysis of the Soxhlet extraction yield by applying different solvents to the different Tara samples.

Parameter	Sample 1	Sample 2	Sample 3
Hexane			
Extraction yield, (%)	8.74	8.63	8.66
Average yield (%)	8.67±0.06		
Acetone			
Extraction yield, (%)	13.80	13.98	13.90
Average yield (%)	13.893±0.09		
Ethanol			
Extraction yield, (%)	10.59	10.40	10.78
Average yield (%)	10.59±0.06		
Isopropyl alcohol			
Extraction yield, (%)	9.91	10.08	10.66
Average yield (%)	10.218±0.40		

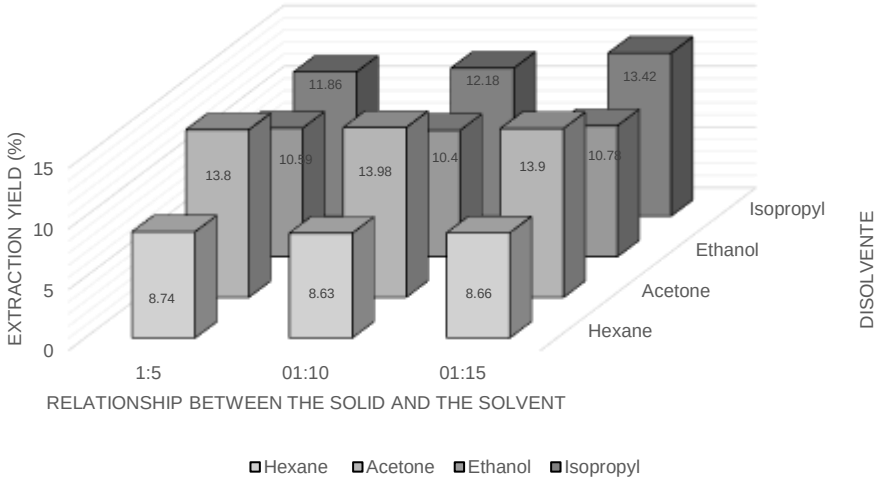

Figure 1: Results obtained in the analysis of Soxhlet extraction performance using different solvents in Tara samples.

3.4. Performance of hydroalcoholic extraction

Table 5 and Figure 2 show the results of the yield in the hydroalcoholic extraction process for the different formulations established in the experimental design (50% ethanol + 50% water; 75% water + 25% ethanol). The average extraction yield in the first formulation was equal to 14.53±0.46, while in the second formulation it was equal to 13.893±0.09.

Table 5: Results obtained in the analysis of hydroalcoholic extraction performance with different solvent formulations.

Parameter	Sample 1	Sample 2	Sample 3
Formulation of 50-50%			
Extract mass (g)	32.69	34.52	32.11
Extraction yield, (%)	14.54	14.98	14.06
Average yield (%)	14.526±0.46		
75-25% formulation			
Mass of extract (g)	13.80	13.98	13.90
Extraction yield, (%)	13.893±0.09		

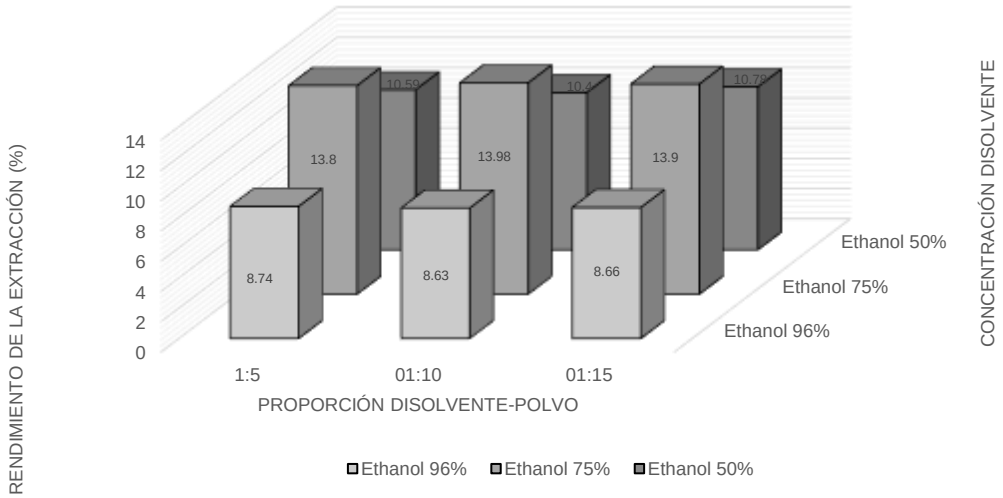

Figure 2: Results obtained in the analysis of the hydroalcoholic extraction performance of different formulations.

3.4. Extraction yield of the second hydroalcoholic step

Table 6 and Figure 3 show the result of the yield in the hydroalcoholic extraction process for the formulation of different methanol concentrations (96.75 and 50%) and different formulations (1:5, 1:10 and 1:15 Tara powder mass/solvent volume). Then, for ethanol concentration equal to 96% in different formulations (1:5, 1:10 and 1:15) the results were equal to 13.44%, 13.39% and 13.47% respectively. For ethanol concentration equal to 75% in different formulation (1:5, 1:10 and 1:15), the results were equal to 14.09%, 14.75% and 13.95% respectively. Finally, for ethanol concentration equal to 96% in different formulation (1:5, 1:10 and 1:15), the results were equal to 11.15%, 11.47% and 11.18% respectively.

Table 6: Results obtained in the analysis of hydroalcoholic extraction performance at different formulation and solvent concentration.

Solvent concentration	**Formulation; mass of powder Tare:volume of solvent (mg/ml)**		
	1:5	01:10	01:15
50% EtOH	13.44	13.39	13.47
75% EtOH	14.09	14.75	13.95
96% EtOH	11.15	11.47	11.18

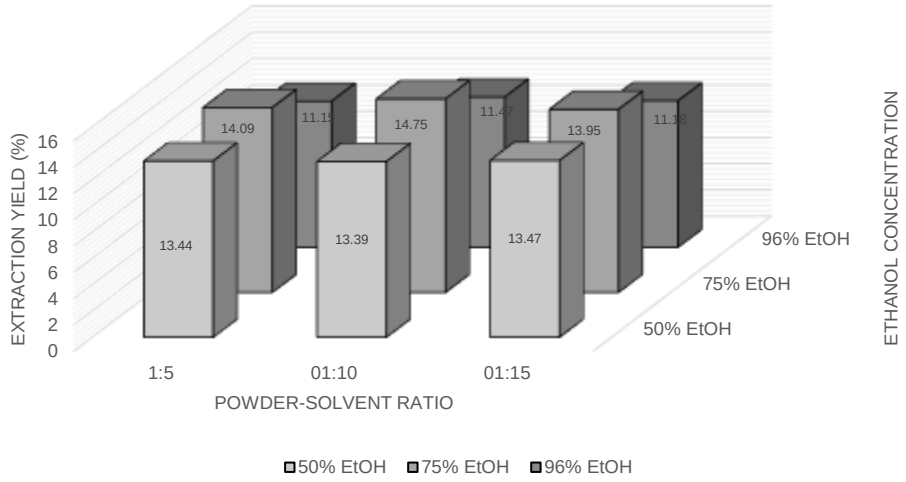

Figure 3: Results obtained in the analysis of hydroalcoholic extraction performance at different formulation and solvent concentration.

4. Conclusions

Based on the analysis of the results, it was possible to verify that the best solvent (other than hydroalcoholic extraction) was acetone with an average extraction yield equal to 13.89%. However, acetone turns out to be very expensive; therefore, it is advisable to perform Soxhlet extraction with ethanol, a process in which an average yield equal to 10.59% was obtained, a lower yield than that generated with acetone; however, the relationship between cost and benefit will be superior for hydroalcoholic extraction compared to the process in which acetone is applied. It was verified that the best technique under the same experimental conditions for hydroalcoholic extraction is ethanol at a concentration equal to 75%, whose average yield was equal to 14.53%. It could also be concluded that the best formulation under the same experimental conditions in the hydroalcoholic extraction is ethanol at a concentration equal to 75% and a ratio equal to 1:10 of Tara powder mass versus solvent volume whose average yield was equal to 14. 26%, which coincides with the results generated by (Ali, 2012), the author who analyzed the performance of Tara extraction with different solvents (water-methanol, water-ethanol and water-acetone), concluding that the best solvent to be used in the extraction of Tara is a mixture of ethanol with water. With this formulation, good economic results can be obtained in production on an industrial scale. The extraction process used is

following that indicated in the publications consulted where it is mentioned that the extraction of tannins can be generated through a single solvent or a mixture of solvents (such as water and ethanol in the hydroalcoholic extraction performed), being the technique using Soxhlet equipment with liquid solvents one of the best processes to separate bioactive compounds, due to the fact that the heating generated in the extraction process increases the removal capacity of compounds that are not soluble at room temperature. (Kusuma, *et al*., 2022).

Tara extracts can be used in the food production industry, cosmetics and in nutritional applications, even in animal diets in the form of natural additives for various purposes related to increased production performance, for example, tannins can be used as antioxidant nutrients or feed additives to reduce methane production in ruminants or even as an additive that improves intestinal health in monogastric and poultry. Tara extracts are a rich source of gallotannins through hydrolysis, which generates a mixture of gallic acid and quinic acid, which can be used in various industrial applications, for example, they can be used in the food industry as an inhibitor agent of microbial growth of pathogenic bacteria, as an antioxidant agent, for example, in edible oils and even as a preventive agent of exposure to neoformed food contaminants (NFCs), for example, in bakery products (Skowyra *et al*., 2013; Aguilar *et al*., 2014; Haslam *et al*., 1962; Romero *et al*., 2012; Pedreschi *et al*., 2018; Pedreschi *et al*., 2022; Ciampi *et al*., 2020; Cardoso *et al*., 2021; Huang *et al*., 2018).

Acknowledgments

Thanks to the Escuela Superior Politecnica de Chimborazo for providing the necessary time and resources for the development of this research work.

References

Aguilar, A. y otros, 2014. Potential of tara (Caesalpinia spinosa) gallotannins and hydrolysates as natural antibacterial compounds. *Food Chemistry*, Volumen 156, pp. 301-304. Online: https://bit.ly/3aSYZIL

Ali, D., 2012. *Extracción de taninos (ácido gálico) a partir del polvo de vaina de tara (Caesalpinia spinosa).* Puno: Universidad Nacional del Altiplano. Online: https://bit.ly/3cq8KON

Araujo, J. & Salas, R., 2009. Actividad antimicrobiana del extracto crudo de la vaina de Caesalpinia spinosa "tara" frente a Staphylococcus aureus. *Científica*, 6(2), pp. 142-155. Online: https://bit.ly/3zkhWgK

ASOCAM, 2022. *Servicio de Gestión del Conocimiento para Latinoamérica y El Caribe.* [En línea] Disponible en: https://bit.ly/3z0rBrk [Último acceso: 2022].

Avilés, R. y otros, 2010. Actividad antioxidante, polifenoles totales y contenido de taninos de extractos de Tara, Caesalpinia Spinosa. *Revista Peruana de Química e Ingeniería Química*, 13(2), pp. 5-11. Online: https://bit.ly/3Oq1z6v

Aybar , J. & Zavala, F., 2016. Efecto Citotóxico del extracto acuoso del pericarpio de Caesalpinia spinosa “tara” en células meristemáticas de Allium cepa L. var. Arequipeña. *Ciencia y Tecnología*, 12(2), pp. 185-193. Online: https://bit.ly/3omiuwo

Ballesteros, R., Durán, M. & Fiorentino, S., 2021. Genotoxicity and mutagenicity assessment of a standardized extract (P2Et) obtained from Caesalpinia spinosa. *Toxicology Reports*, Volumen 8, pp. 258-263. Online: https://bit.ly/3ROyyUZ

Bellotti, N., Del Amo, B. & Romagnoli, R., 2012. Caesalpinia spinosa tannin derivatives for antifouling formulations. *Procedia Materials Science*, Volumen 1, pp. 259-265. Online: https://bit.ly/3OnXSOL

Borzelleca, J., Ladu, B., Senti, F. & Egle, J., 1993. Evaluation of the safety of tara gum as a food ingredient: a review of the literature. *Journal of the American College of Toxicology*, 12(1), pp. 81-89. Online: https://bit.ly/3yXuQjt

Callohuari, R., Sandoval, . V. & Huamán, G., 2017. Gastroprotective effect and antioxidant capacity of the aqueous extract of the pods of Caesalpinia spinosa "tara" in experimental animals. *Anales de la Facultad de Medicina*, 78(1), pp. 61-66. Online: https://bit.ly/3aWaX4d

Cardoso, E. y otros, 2021. Effect of tannins from tropical plants on methane production from ruminants: A systematic review. *Veterinary and Animal Science*, Volumen 14, p. 100214. Online: https://bit.ly/3S29PwK

Chambi, F. y otros, 2013. Antioxidant potential of hydrolyzed polyphenolic extracts from tara (Caesalpinia spinosa) pods. *Industrial Crops and Products*, Volumen 47, pp. 168-175. Online: https://bit.ly/3Pp8Q83

Choudhary, P. y otros, 2021. Comparative phenolic content and antioxidant activity of some medicinal plant extracts prepared by choline chloride based green solvents and methanol. *Current Research in Green and Sustainable Chemistry*, Volumen 4, p. 100224. Online: https://bit.ly/3yXV7xV

Ciampi, F. y otros, 2020. Evaluation of natural plant extracts as antioxidants in a bovine in vitro model of oxidative stress. *Journal of Dairy Science*, 103(10), pp. 8938-8947. Online: https://bit.ly/3IVsx4Q

Cuyan, M., 2019. *Comparación entre el efecto del extracto hidroetanólico de semillas de caesalpinia spinosa (tara), hipoclorito al 5,25% y gluconato de clorhexidina al 2% en la desinfección in vitro de conos de gutapercha ontaminados con enterococcus faecalis atcc 29212*. Pimentel: Universidad Señor de Sipán. Online: https://bit.ly/3yPGe0E

Das, A. y otros, 2020. Review on tannins: Extraction processes, applications and possibilities. *South African Journal of Botany*, Volumen 135, pp. 58-70. Online: https://bit.ly/3znXr2I

De la Cruz, O., 2004. Aprovechamiento integral de la Tara (Caesalpinia spinosa). *Revista Del Instituto de Investigación FIGMMG*, 7(15), p. 64–73. Online: https://bit.ly/3yUTUYh

Dirar, A. y otros, 2019. Effects of extraction solvents on total phenolic and flavonoid contents and biological activities of extracts from Sudanese medicinal plants. *South African Journal of Botany*, Volumen 120, pp. 261-267. Online: https://bit.ly/3yZOGdR

Gaidau, C. y otros, 2014. Tara tannin extract improvement I. Extraction and concentration through membranary filtration techniques. *Revista de Chimie*, 65(8), pp. 929-933.

Garro, J., Riedl, B. & Conner, A., 1997. Analytical Studies on Tara Tannins. *Holzforschung*, 51(3), pp. 235-243. Online: https://bit.ly/3ISMWrr

Haslam, E., Haworth, R. & Keen, P., 1962. 737. Gallotannins. Part VII. Tara gallotannin. *Journal of the Chemical Society (Resumed)*, Volumen 10, pp. 3814-3818. Online: https://bit.ly/3zloEDg

Hrůzová, K., Matsakas, L., Rova, U. & Christakopoulos, P., 2021. Organosolv fractionation of spruce bark using ethanol–water mixtures: Towards a novel bio-refinery concept. *Bioresource Technology*, Volumen 341, p. 125855. Online: https://bit.ly/3zku5ST

Huang, Q. y otros, 2018. Potential and challenges of tannins as an alternative to in-feed antibiotics for farm animal production. *Animal Nutrition*, 4(2), pp. 137-150. Online: https://bit.ly/3PL1X0x

Isaza, J., 2007. Taninos o polifenoles vegetales. *Scientia et technica*, 1(33), pp. 13-18. Online: https://bit.ly/3RTQRIk

Kumar, K., Srivastav, S. & Sharanagat, V., 2021. Ultrasound assisted extraction (UAE) of bioactive compounds from fruit and vegetable processing by-products: A review. *Ultrasonics Sonochemistry*, Volumen 70, pp. 1-11. Online: https://bit.ly/3aYXmsX

Kusuma, S., Wulandari, S., Nurfitriani, R. & Awaludin, A., 2022. The potential solvent for tannin extraction as a feed additive made of coffee husk (Coffea canephora) using Soxhlet Method. *In IOP Conference Series: Earth and Environmental Science*, 980(1), p. 012024. Online: https://bit.ly/3zklBeu

Li, Z., Yang, F., Yang, L. & Zu, Y., 2016. Ultrasonic extraction of oil from Caesalpinia spinosa (Tara) seeds. *Journal of Chemistry*, Volumen 2016, p. 6. Online: https://bit.ly/3z0wuka

Marín, J., 2022. *Obtención de un extracto optimizado de polifenoles de Vainas de tara (caesalpinia spinosa) por altas presiones Hidrostáticas y su aplicación en un producto horneado Con el fin de mitigar el contenido de neo-contaminantes.* Santiago: Universidad de Chile. Online: https://bit.ly/3znZl3m

Nuñez, W. & Quispe, R., 2015. *Evaluación antioxidante y antienzimática in vitro y antiinflamatoria in vivo del extracto hidroalcohólico de la Caesalpinia spinosa "tara".* Lima: Universidad Nacional de San Marcos. Online: https://bit.ly/3IWmHA7

Nuñez, W. y otros, 2016. Actividad antioxidante y antienzimática in vitro antinflamatoria in vivo del extracto idroalcohólico de Caesalpinia Spinosa "Tara". *Ciencia e Investigación*, 19(1), pp. 35-42. Online: https://bit.ly/3OoZ4S2

Pedreschi, F. y otros, 2022. Effect of the Integrated Addition of a Red Tara Pods (Caesalpinia spinosa) Extract and NaCl over the Neo-Formed Contaminants Content and Sensory Properties of Crackers. *Molecules 2022*, 27(3), pp. 1-11. Online: https://bit.ly/3PGPMBZ

Pedreschi, F. y otros, 2018. Tara pod (Caesalpinia spinosa) extract mitigates neo-contaminant formation in Chilean bread preserving their sensory attributes. *LWT*, Volumen 95, pp. 116-122. Online: https://bit.ly/3Px0mvO

Rojas, N. y otros, 2011. Tratamiento de quemaduras con películas obtenidas por radiación gamma que contienen extracto hidroalcohólico de tara (Caesalpinia spinosa) en animales de experimentación. *Dermatología Peruana*, 21(1), pp. 6-12. Online: https://bit.ly/3PumUgG

Romero, N., Fernández, A. & Robert, P., 2012. A polyphenol extract of tara pods (Caesalpinia spinosa) as a potential antioxidant in oils. *European Journal of Lipid Science and Technology,* 114(8), pp. 951-957. Online: https://bit.ly/3yWWGwe

Sánchez, J., Beltrán, J. & Gragera, J., 2011. Caesalpinia spinosa and Castanea sativa tannins: A new source of biopolymers with adsorbent capacity. Preliminary assessment on cationic dye removal. *Industrial Crops and Products*, 35(1), pp. 1238-1240. Online: https://bit.ly/3ojd6Kf

Sandoval, . T. y otros, 2016. Standardized Extract from Caesalpinia spinosa is Cytotoxic Over Cancer Stem Cells and Enhance Anticancer Activity of Doxorubicin. *The American Journal of Chinese Medicine*, Volumen 44, pp. 1-25. Online: https://bit.ly/3PLCB2u

Santos, M., de Carvalho, C. & Garcia, E., 2021. Microencapsulation of vitamin D3 by complex coacervation using carboxymethyl tara gum (Caesalpinia spinosa) and gelatin A. *Food Chemistry*, Volumen 343, p. 128529. Online: https://bit.ly/3Ork4r8

Seabra, I., 2010. *Extraction of valuable compounds from agro-residues of elder (Sambucus nigra), pine (Pinus pinaster) and tara (Caesalpinia spinosa).* Coimbra: University of Coimbra. Online: https://bit.ly/3aTwieu

Skowyra, M. y otros, 2013. Antioxidant properties of aqueous and ethanolic extracts of tara (Caesalpinia spinosa) pods in vitro and in model food emulsions. *Journal of the Science of Food and Agriculture*, 94(5), pp. 911-918. Online: https://bit.ly/3cwuecK

Wischer, G. y otros, 2013. Effects of different tannin-rich extracts and rapeseed tannin monomers on methane formation and microbial protein synthesis in vitro*. *Animal*, 7(11), pp. 1796-1805. Online: https://bit.ly/3PLZl2o