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Artículos Científicos

Antioxidantes naturales y su poder reductor frente a iones plata: alternativa en la recuperación de metales

Natural Antioxidants and Their Reducing Power Against Silver Ions: Alternative in the Recovery of Metals

Antioxidantes naturais e seu poder redutor contra íons de prata: alternativa na recuperação de metais

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Resumen

La contaminación de las aguas de ríos y mares por la presencia de metales es un problema de escala mundial debido principalmente al impacto de los relaves mineros. Se ha demostrado científicamente que, además de causar algunos de los problemas ambientales más graves, la exposición a metales en determinadas circunstancias es la causa de la degradación y muerte de vegetación, ríos, animales e incluso de daños directos en el ser humano, por lo que es esencial buscar formas para eliminarlos, o al menos reducir su impacto.

Este trabajo muestra los resultados obtenidos del comportamiento reductor de extractos de plantas frente a iones de plata, un proceso donde, en lugar de usar reactivos sintéticos, método simple y económico, los extractos son químicos utilizados como reactivos en la recuperación de un metal. Extractos que contienen sustancias antioxidantes como flavonoides, taninos y compuestos fenólicos, que son metabolitos secundarios de muchas plantas, cuya actividad antioxidante desempeña un papel fundamental en los procesos de reducción. Los extractos de plantas estudiados fueron los siguientes: diente de león (*Taraxacun officianale*), perejil (*Petroselinum crispum*) y hierbabuena (*Camellia sinensis*). Se realizaron pruebas analíticas de la identificación cualitativa de la presencia en los extractos acuosos de los flavonoides, ácidos fenólicos responsables de su poder reductor.

El poder reductor de los extractos fue probado a través de la formación de nanopartículas de plata, y monitoreando los espectros UV-Vis con la aparición de la banda del plasmón característico de nanopartículas metálicas, así como a través de la recuperación de la plata en forma de sólido limpio y brillante con buenos rendimientos, se cuantificó el rendimiento de la plata obtenida con cada uno de los extractos de plantas utilizados. A partir de los resultados obtenidos se puede concluir que es viable utilizar extractos vegetales para la reducción de metales y de esta forma recuperar metales en forma metálica.

Palabras clave: extracto vegetal, metales, nanopartículas, plata, reductor.

Abstract

The contamination of the waters of rivers and seas due to the presence of metals is a worldwide problem mainly due to the impact of mining tailings. It has been scientifically proven that, in addition to causing some of the most serious environmental problems, exposure to metals in certain circumstances is the cause of the degradation and death of vegetation, rivers, animals and even of direct damage to humans, by what is essential look for ways to eliminate them, or at least reduce their impact.

This work shows the results obtained from the reducing behavior of plant extracts against silver ions, a process where the extracts are chemicals used as reagents in the recovery of a metal instead of using synthetic reagents, simple and economical method. Extracts containing antioxidant substances such as flavonoids, tannins and phenolic compounds, which are secondary metabolites of many plants, and their antioxidant activity play a fundamental role in the reduction processes. The plant extracts studied were: Dandelion (Taraxacun officianale), Parsley (Petroselinum crispum) and Hierbabuena (Camellia sinensis). Analytical tests of the qualitative identification of the presence in the aqueous extracts of the flavonoids, phenolic acids responsible for their reducing power, were carried out.

The reducing power of the extracts was tested through the formation of silver nanoparticles, monitoring the UV-Vis spectra with the appearance of the plasmon band characteristic of metallic nanoparticles, as well as through the recovery of silver in the form of clean and bright solid with good yields, the yield of the silver obtained with each of the plant extracts used was quantified.

From the results obtained it can be concluded that it is feasible to use plant extracts for the reduction of metals and in this way recover metals in metallic form.

Keywords: plant extract, metals, nanoparticles, silver, reducer.

Resumo

A contaminação das águas dos rios e mares devido à presença de metais é um problema mundial devido principalmente ao impacto dos rejeitos de mineração. Está cientificamente provado que, além de causar alguns dos mais sérios problemas ambientais, a exposição a metais em certas circunstâncias é a causa da degradação e morte de vegetação, rios, animais e até mesmo danos diretos aos humanos, então que é essencial procurar maneiras de eliminá-las ou, pelo menos, reduzir seu impacto.

Este trabalho mostra os resultados obtidos a partir do comportamento redutor de extratos vegetais contra íons de prata, processo em que, ao invés de utilizar reagentes sintéticos, método simples e barato, os extratos são produtos químicos utilizados como reagentes na recuperação de um metal. Extratos contendo substâncias antioxidantes, como flavonóides, taninos e compostos fenólicos, que são metabólitos secundários de muitas plantas, cuja atividade antioxidante desempenha um papel fundamental nos processos de redução. Os extratos das plantas estudadas foram: dente de leão (Taraxacun officianale), salsa (Petroselinum crispum) e hortelã (Camellia sinensis). Testes analíticos foram realizados na identificação qualitativa da presença nos extratos aquosos dos flavonóides, ácidos fenólicos responsáveis pelo seu poder redutor.

O poder redutor dos extratos foi testado através da formação de nanopartículas de prata, e pela monitoração dos espectros UV-Vis com o aparecimento da faixa de plasmon característica das nanopartículas metálicas, bem como pela recuperação de prata na forma de nanopartículas. de sólido limpo e brilhante com bons rendimentos, o rendimento da prata obtida com cada um dos extractos de plantas utilizados foi quantificado. A partir dos resultados obtidos pode-se concluir que é viável a utilização de extratos vegetais para a redução de metais e, desta forma, recuperar metais em forma metálica.

Palavras-chave: extrato vegetal, metais, nanopartículas, prata, redutor.

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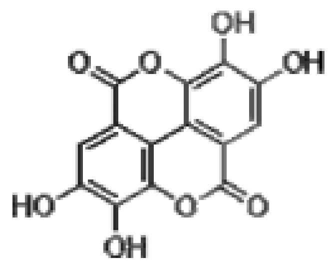
Introduction

Pollution of river and sea waters due to the presence of metals is a world-wide problem mainly due to the impact of mining tailings, as well as wastes from the metallurgical industries. It has been scientifically proven that, in addition to causing some of the most serious environmental problems, exposure to metals in certain circumstances is the cause of the degradation and death of vegetation, rivers, animals and even direct damage to humans. Of the more than 106 elements currently known, 84 are metals, so it is not surprising that the possibilities of metal contamination in the environment are numerous. Keep in mind that metals are natural materials that have played a fundamental role in the development of civilizations. The problem arises when its industrial use proliferates and its increasing use in everyday life ends up affecting health; In fact, population growth in urban areas and rapid industrialization have caused serious problems of pollution and deterioration of the environment, especially in developing countries. Many metals such as silver, copper and zinc end up dissolved in the waters of rivers and seas because the salts they form are soluble in water, and when their concentrations are higher than normal and produce harmful effects they are considered pollutants, which undoubtedly affects the flora and fauna, as well as the human being. Therefore, its elimination or recovery, or at least a decrease in its impact is very important (Nava, 2011).

Commonly the usual techniques for cleaning these waters contaminated with metals are chemical techniques in which chemical substances are used as reducing agents. The problem with these techniques is either their high cost, or their high toxic level due to the reagents used. Taking into account both factors, scientists have resorted, instead of toxic chemicals, to the use of plants capable of reducing cations in a metal salt solution (García, García, Rojo and Sánchez, 2001), so in recent years years have increased interest in the search for natural antioxidants, generally consisting of mixtures of compounds with high molecular diversity and biological functionality, obtained from plant extracts, among which the most important are polyphenolic compounds such as flavonoids, tannins and phenolic compounds , secondary metabolites of many plants that play a fundamental role in antioxidant activity due to their low redox potentials, as they act as electron donors that produce their oxidation, thus inhibiting other oxidative processes (Han, Zhang and Skibsted, 2012). The low redox potentials of these antioxidants make the reduction of the vast majority of free radicals and some metals thermodynamically favorable. (Makarov *et al*., 2014).

The compounds whose structure has at least one aromatic ring substituted with one or more hydroxyl groups belong to the group of polyphenols or polyphenolic compounds, and are found mainly in nature in biomass such as vegetable fruits, seeds and derived products. Figure 1 shows its chemical structure.

Figura 1. Estructura química de los polifenoles



Fuente: Naczk y Shahidi (2006)

From the simplest structure to long chains of aromatic rings, polyphenols constitute a broad group of phytochemicals with various properties and functions involved in the growth and development of plants. Some of these compounds provide pigmentation and others are antioxidants that are involved in tissue protection, either against ultraviolet (UV) radiation or certain pathogens, or against cell aging (Ignat, Volf and Popa, 2011).

Without a doubt, the synthesis of metallic nanoparticles is evidence of the reducing power of plant extracts, which, it should be emphasized, will depend on the components that the plant contains. The formation of metal nanoparticles is carried out by a mechanism that starts from the initial reduction of metal ions that induces the formation of nucleation centers. These centers sequester additional metal ions and also incorporate neighboring nucleation sites that sometimes lead to the formation of nanoparticles (García, 2001).

Taking into account the great diversity of vegetables that exist, as well as their availability, and that not only would reduce the costs of chemical procedures, but would also be a more environmentally friendly procedure, without forgetting the contribution of research in chemistry The objective of this work was to study the plant extracts of dandelion (Taraxacun officianale), parsley (Petroselinum crispum) and peppermint (Mentha piperita, sativa, spicata) as natural antioxidants and determine their reducing power against silver ions; all this as an alternative to the toxic processes of metal recovery. The choice of these extracts is motivated by their high availability and low cost. In short, it not only avoids the use of chemical reducing agents in many expensive and toxic cases, but also results in a more economical and ecological method.

In this regard, its reducing power was verified through the formation of silver nanoparticles through the use of UV-Vis spectra: its presence was identified by the appearance of localized surface plasmons, characteristic of metal nanoparticles whose quantum nature is a direct consequence of the small size of the nanoparticles, and that most of their atoms are on the surface (Cruz et al., 2012). On the other hand, its reducing power was verified with the reduction of ionic silver to metallic silver through the reaction of the diaminplate coordination compound (I) with the plant extracts, thanks to which the silver was recovered as a solid , clean and bright with good yields.

Table 1 shows the vegetables used in this work.

Tabla 1. Vegetales utilizados

Vegetal	Nombre científico
Perejil	*Petroselinum crispum*
Hierbabuena	*Mentha piperita*
Diente de león	*Taraxacun officianale*

Fuente: Elaboración propia

Parsley (*Petroselinum*)

Botanically, parsley is a 30-80 cm tall plant, with an erect stem, curly and thick leaves, with long, conical, white or ocher primary roots. It is an aromatic herb belonging to the Apiaceae or Umbelliferae family. It has different and important chemical components, such as flavonoids, apiol, phytol, essential oils, coumarins and petroselinic acid, among others. (Fonnegra y Jiménez, 2007).

Dandelion (Taraxacum officinale)

Dandelion leaves are made up of flavonoids and coumarins; The former have anti-cancer characteristics that lower cholesterol levels, in addition to presenting antioxidant properties. It is a plant that is also made up of tannins, which have antioxidant properties, as do alkaloids and saponins. They have a bitter taste due to eudesmano type principles, which are part of their constitution (Gimeno, 2000).

Peppermint (Mentha piperita)

Peppermint leaves are elliptic-lanceolate type, long petiolate and with a serrated or serrated margin, hairy on both sides, very deep green. The pleasant smell is due to menthol, a component of its essential oils. The leaf has been widely studied and contains, among other components, essential oil (menthol, chin, cineole) and flavonoids (diosmin, eriocitrine, hesperidin, narirutin, luteolin, rutinoside, among others) that give it its characteristic smell and give it In addition, its pharmacological properties (Guedon and Pasquier, 1994).

Figure 2 shows the image of the three vegetables studied.

Figura 2. Imagen de vegetales estudiados

Fuente: Elaboración propia

Silver

The noble metal chosen to check the antioxidant power of vegetables was silver — with a standard reduction potential of 0.7966 Eo / V—; Shiny, resistant, ductile and malleable metal. Of all metals, it has the highest reflective optical white color and the highest thermal and electrical conductivity. From the chemical point of view, it is one of the heavy and noble metals; from a commercial point of view, it is a precious metal (Brown, 2004).

It is a natural resource whose current demand is greater than its production: the photographic industry is the largest consumer of silver in the world because it is unique in its ability to react with light and produce images in applications, such as photography, and in the preparation of radiographic plates (Cabrero, 2004). This product is the most important input of the X-ray service of any hospital or clinic in the world; unfortunately, once the radiographic plates have fulfilled their function, they end up being completely discarded and it can be said that the silver contained in the radiographs goes to rivers and seas; silver that is rinsed from the radiographic films and once it is diluted it is very difficult to recover it. Currently, there are methods to recover silver from waste generated by the photographic sector. The most common reported in the literature are chemical methods that include metal replacement or replacement, electrolysis, ion exchange and precipitation. These techniques are usually related to a high initial cost in terms of equipment, operation and purification of the final products.

The use of plant extracts is an option for recovery, since they contain in their structure powerful antioxidants such as polyphenolic compounds and flavonoids, capable of reducing ionic silver to metallic silver. The effectiveness of the method is that the reducing agent has a lower standard potential than silver in order to reduce its metal ions of greater standard potential. There are two spontaneous electrochemical processes of electron donation and acceptance, acceptance and donation are the product of electron transfer (Skoog, West, Holler y Crouch, 2005).

Materials and methods

The reagents used, namely, $AgNO_3$, AgCl y NH_4OH, they were from the supplier Sigma-Aldrich. Deionized water was used in all tests. The dandelion (Taraxacun officianale), parsley (Petroselinum crispum) and peppermint (Mentha piperita) plants used in this experiment were acquired from the market in the municipality of San Pedro Cholula, Puebla.

All glassware was washed with running water and subsequently with deionized water.

Preparation of extracts

The preparation of the extracts of each of the plants, namely dandelion (Taraxacun officianale), parsley (Petroselinum crispum) and peppermint (Mentha piperita), was carried out by a solid-liquid extraction process in them temperature conditions, contact time and proportion of biomass-solvent. As a solvent, water was used because of its high polyphenol extraction capacity and that it has no toxicity (Naczk and Shahidi, 2006). The plant extracts were prepared using 1.0 g of each of them (dandelion, parsley and peppermint) in 100 ml of boiled distilled water until a volume of 70 ml was obtained. This infusion was filtered with Whatman 5 paper and allowed to cool. Figure 3 shows the images of the plant extracts obtained.

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Figura 3. Extractos vegetales

a) Diente de león (*Taraxacum officinale*)   b) Perejil (*Petroselinum crispum*)   c) Hierbabuena (*Mentha piperita*)

Fuente: Elaboración propia

Polyphenol Identification

The identification of phenolic, flavonoid and tannin compounds was carried out through the Shinoda qualitative tests for flavonoids (a pink, red, violet or orange color indicates a positive positive test), of the gelatin-salt test for tannins (green, blue or black precipitate indicates that the test is positive) and the test of the $FeCl_3$ for phenolic compounds (from a green, blue or black color the test is considered positive) (Bravo y Acuña, 2015).

Flavonoid test: Shinoda test

To 1 ml of solution in a clean test tube magnesium filings were added while holding the tube with a clamp. Concentrated HCl (37% purity) was carefully added through the tube wall until the end of gas evolution.

A pink, red, violet or orange coloration indicates a positive test for flavonoids.

Test for phenolic compounds: FeCl3 test

To 1 ml of solution in a clean test tube was added a drop of 1% aqueous or alcoholic FeCl3 and mixed.

The appearance of green, blue or dark coloration is considered positive test.

Tannin test: jelly-salt test

To 1 ml of solution in a clean test tube was added 1 ml of the gelatin-salt reagent. Precipitation formation is considered a probably positive test.

Decant the supernatant and add three drops of FeCl3: if there is a green, blue or black precipitate the test is considered positive.

Evidence of the effectiveness of plant extracts as reducing agents against silver

In order to determine the reducing power of the extracts, we proceeded in the following two ways.

Nanoparticle formation

Aqueous solutions of $AgNO_3$ of concentration 10^{-3} M. To these solutions a defined volume of the extracts (1-4 mL) was added and they were filled with deionized water to a volume of 10 ml. At the time the plant extracts were added, they took a yellow color characteristic of the formation of silver nanoparticles. The UV-Vis spectra of the three colloidal solutions obtained from the reduction of silver with the plant extracts were performed with a double beam spectrophotometer in a wavelength range between 350 and 700 nm using 1 cm path cuvettes optical.

Reduction of ionic silver to metallic silver

The reduction of ionic silver to metallic silver was taken from the silver chloride obtained from the reaction of a silver nitrate solution that is reacted with NH_4Cl. A 1.7 g of silver chloride was reacted with 30 ml of 30% ammonium hydroxide, in order to prepare the diaminplate coordination compound (I).

The reduction of ionic silver to metallic silver was carried out from the diaminplate coordination compound (I). The addition of the extracts to this coordination compound led to the precipitation of silver in the form of metal.

Results and Discussion

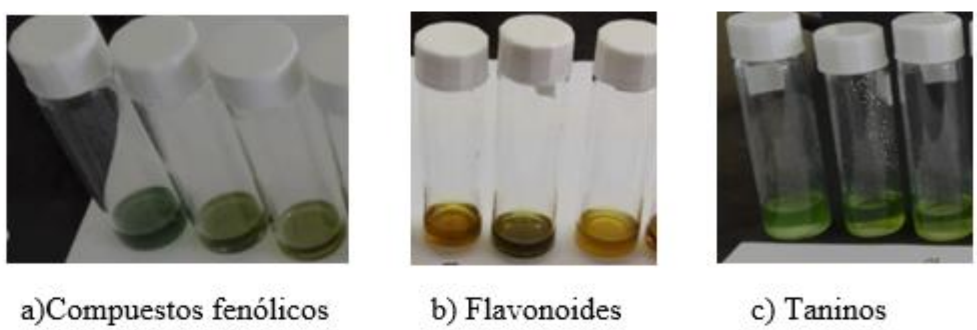
The identification of phenolic, flavonoid and tannin compounds that was carried out through qualitative tests was positive for the three plant extracts; showed colorations and the presence of precipitates due to the presence of phenolic compounds, flavonoids and tannins.

For the identification of phenols, the FeCl3 assay was used. Figure 4 shows the photograph of the identification of phenolic acids contained in the extracts, where a yellowish green color characteristic of their presence can be seen (Ignat, 2011).

The Shinoda test-test was used to identify the presence of flavonoids, a test that is considered positive for flavonoids if it has a pink, red, violet or orange color. As can be seen in Figure 4, the plant extracts used have an orange color.

For the qualitative identification of the tannins present in the extracts, the gelatin-salt test was used, a test that is considered positive for tannins if a precipitate forms. In the case of the extracts used in this work, the test was positive in all cases; The precipitate proves the presence of tannins. Figure 4 shows the precipitate formed (Miranda, 2012).

Figura 4. Pruebas químicas cualitativas de la presencia de polifenoles



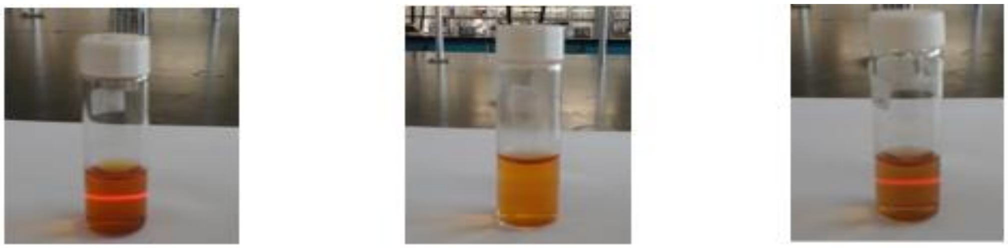
Fuente: Elaboración propia

Reduction of silver with plant extracts

Nanoparticle formations

The addition of the plant extracts to the 0.001 M silver nitrate solution resulted in yellowish solutions with colloidal properties characteristic of silver nanoparticles. Figure 5 shows the colorations of each of them.

Figura 5. Disoluciones de nanopartículas obtenidas con los extractos



a) Diente de león (Taraxacum officinale) b) Perejil (Petroselinum crispum) c) Hierbabuena (Menta piperita)

Fuente: Elaboración propia

These solutions were analyzed by UV-Vis spectroscopy for six hours: from the moment the defined volume was added until stabilization. The spectra obtained show in all three cases the appearance of the plasmon band - characteristic of silver metal nanoparticles - as a result of the reduction of silver caused by the presence of extracts that perform the role of reducing agents.

Among the fascinating properties of metal nanoparticles, the appearance of characteristic, localized surface plasmons, whose quantum nature is a direct consequence of the small size of metal nanoparticles, the development of well-defined crystalline nanocares and that most of their atoms stand out they are on the surface, that is, that the proportion of atoms on the surface with respect to volume is much higher than that of the metal sine (Cruz et al., 2012).

Figure 6 shows the UV-Vis spectrum made with the colloidal solution, obtained with peppermint extract. A plasmon band with a maximum absorbance at 410 nm is observed, with an amplitude between 350-450 nm, which confirms the obtaining of silver nanoparticles and the reducing power of peppermint extract (Monge, 2009).

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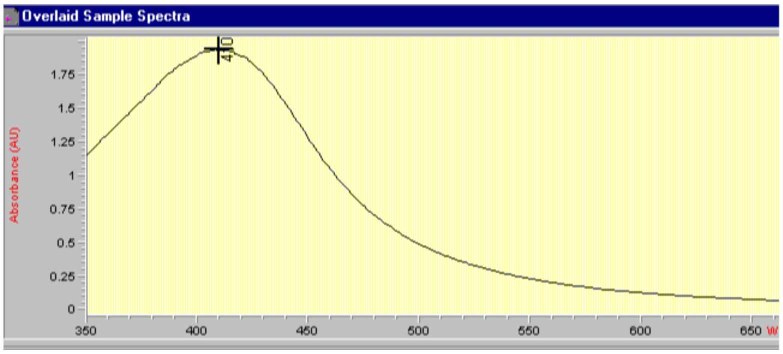
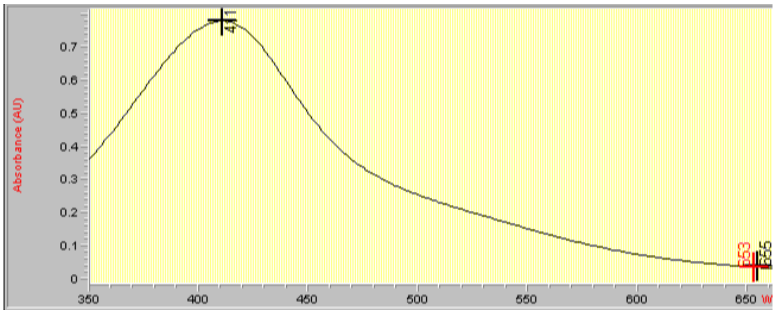
Figura 6. UV-Vis realizado con la solución obtenida con el extracto de hierbabuena y los iones plata.



Fuente: Elaboración propia

And Figure 7, on the other hand, shows the UV-Vis spectrum made with the solution obtained with the dandelion extract and the 0.001 M aqueous solution of silver nitrate. A band at 424 nm is shown, which also confirms the obtaining of silver nanoparticles and the reducing power of dandelion extract (Monge, 2009).

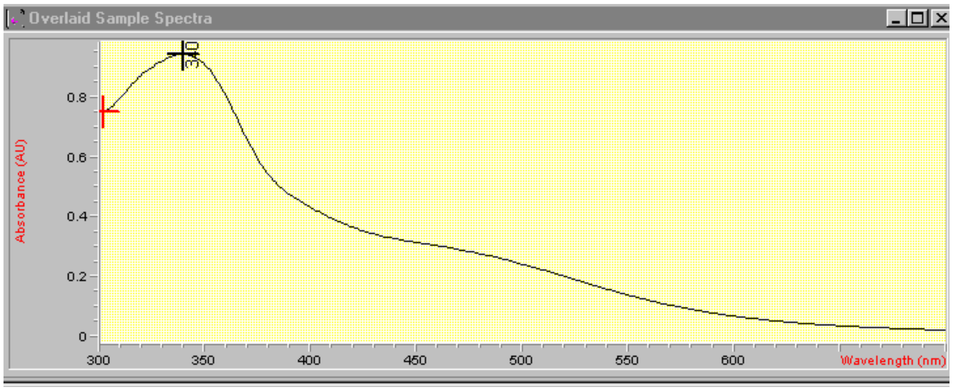
Figura 7. UV-Vis de las nanopartículas de plata obtenidas con el extracto de hoja de diente de león



Fuente: Elaboración propia

Finally, Figure 8 shows the UV-Vis spectrum of the reaction of silver nitrate (I) and parsley extract. A band is observed at a wavelength of 340 nm; band that is within the size range of metal nanoparticles.

Figura 8. UV-Vis de la reacción del nitrato de plata (I) y extracto de perejil



Fuente: Elaboración propia

Table 2 summarizes the wavelengths in which the absorbance band appears when the metal salts react with the different extracts studied in this work.

Tabla 2. Longitudes de onda observadas en los espectros de UV-vis

Sales metálicas + Extracto	**Longitud de onda (nm)**
$AgNO_3$ + Hierbabuena (*Mentha piperita*)	410
$AgNO_3$ + Diente de león (*Taraxacun officianale)*	411
$AgNO_3$ + Perejil (*Petroselinum crispum)*	340

Fuente: Elaboración propia

It is evident that the three plant extracts used showed evidence of their reducing power, the UV-Vis spectra reveal the formation of plasmon in the range of 340 nm and 410 nm, characteristic of the formation of silver nanoparticles.

Reduction of ionic silver to metallic silver

The reduction of ionic silver to metallic silver by the addition of plant extracts started from the formation of silver chloride from a solution of silver nitrate with ammonium chloride. Equation 1 shows the chemical reaction.

$$AgNO_{3(ac)} + NH_4Cl_{(ac)} \longrightarrow AgCl_{(s)} + NH_4NO_3 \quad (1)$$

The silver chloride obtained was used to obtain the diaminplate coordination compound (I), as shown in equation 2.

$$AgCl_{(s)} + 4NH_{3(l)} + H_2O \longrightarrow 2Ag(NH_3)_2^+{}_{(ac)} + 2OH^-{}_{(ac)} \quad (2)$$

Silver is a metal is a very electropositive metal (+0.799 V), and is displaced from the solution by virtually all metals (Bard and Faulkner, 2001), which causes it to deposit with great speed in the form of black powder without No adhesion, according to the following reaction:

$$Ag(ac) + e^- = Ag^0(s)\ E^0 = +0.799\ V$$

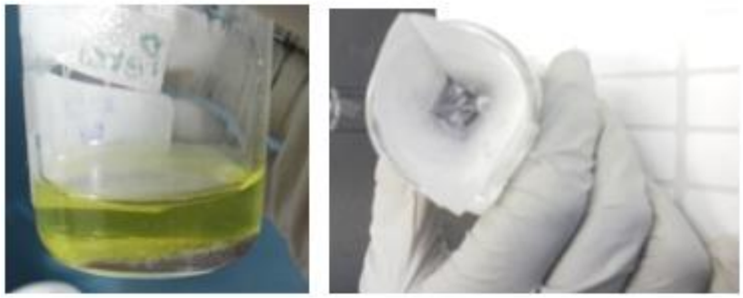
The only way to avoid this inconvenience is to shift the potential towards more electronegative values; for example, by decreasing the concentration of Ag + ions in the solution. In practice this is achieved using complex salts, such as diaminplate.

[Ag (NH3) 2] + is a very weak oxidant with an oxidation potential (0.376 V) that reacts with the components of plant extracts in aqueous solution. No doubt this gave rise to silver ions to gain electrons. Thus, the metallic silver was deposited in the bottom of the container as a result of the reduction of the silver from Ag1 + to Ag0 (s). The addition of aqueous vegetable extracts to the diaminplate (I) succeeded in reducing ionic silver to metallic silver. Equation 3

$$\text{Extracto vegetal (acuoso)} + [Ag(NH_3)_2]^+(ac) \longrightarrow Ag(s) \quad (3)$$

Silver in metallic form was precipitated to the bottom of the vessel, filtered, washed 4 times with 5 ml of water and finally weighed. This operation was carried out with each of the extracts: peppermint, dandelion and parsley. Figure 9 shows the silver precipitated in the bottom of the container, as well as the silver obtained in the filter paper. In the case of the use of peppermint extract, a clean silver with a shiny appearance is obtained.

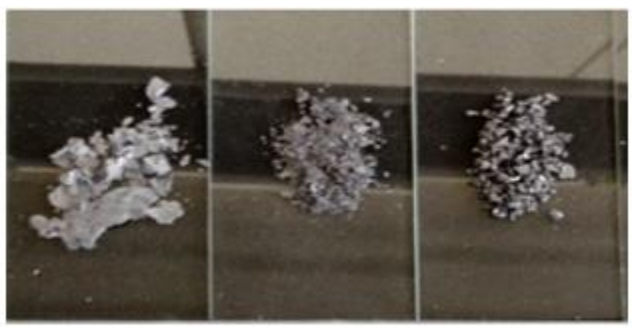
Figura 9. Plata en el fondo del recipiente y en el papel de filtro



Fuente: Elaboración propia

The precipitated silver is obtained in the form of flakes and very fine powder with the three vegetable extracts. It was necessary to wash several times because there were residues of the extracts used, most likely by-products that formed in the course of the reaction. Figure 10 shows the appearance of the recovered silver with each of the aqueous extracts.

Figura 10. Plata metálica obtenida con los extractos de perejil, diente de león y hierbabuena



a) Perejil *b)* Diente de león *c)* Hierbabuena

Fuente: Elaboración propia

The silver obtained from 1.5 g AgCl and through the use of plant extracts was weighed for each case. The silver recovered with the parsley extract was 0.8816 g; Peppermint was 1.0238 g, and for dandelion it was 0.9623 g. The results reveal that the peppermint aqueous extract showed greater capacity to reduce ionic silver to metallic silver.

Table 3 shows once more the quantities of silver obtained in each of the samples used.

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Tabla 3. Cantidad de plata recuperada de 1.5 g de AgCl.

Extractos acuosos	Plata recuperada (g)
Perejil (*Petroselinum crispum)*	0.8816
Hierbabuena (*Mentha piperita*)	1.0238
Diente de león (*Taraxacun officianale)*	0.9623

Fuente. Elaboración propia

Conclusions

Qualitative tests of the presence of flavonoids, phenolic acids and tannins in the three extracts were positive.

The reducing power of the plant extracts of dandelion (Taraxacun officianale), parsley (Petroselinum crispum) and peppermint (Mentha piperita, sativa, spicata) plants against silver ions was checked; They act as natural antioxidants, as an alternative in metal recovery.

The UV-Vis spectra highlight the reducing power of plant extracts of dandelion, parsley and peppermint.

The surface plasmon that appears between 400 nm and 600 nm is evidence of the formation of metallic nanoparticles due to the gain of electrons.

It is clear that, by synthesizing metal nanoparticles from this method, it is possible to reduce manufacturing costs and the negative impact on the environment because the reducing agent used is natural.

From the reaction of the diaminplate (I) with the three extracts it was possible to reduce the silver and obtain it in the form of metallic flakes.

From the results obtained, it can be concluded that it is feasible to use plant extracts for the reduction of metals and thus recover metals in metallic form.

It is important to carry out more studies on the nanoparticles obtained, with other spectroscopies that help us to corroborate the reduction of metals with plant extracts.

Finally, it is considered that the reduction of metals with plant extracts is a viable alternative to recover metals and reduce pollution in the process.

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