Modeling of *Psiadia altissima* (Asteraceae) solutes extraction, in aqueous and alcoholic media

Lovasoa RAKOTONDRAMASY-RABESIAKA[1,*], Radotiana RAKOTONDRAFARA[2],

Mihasina RABESIAKA[2], Amélie RAHARISOLOLALAO[1]

[1]Laboratoire de Chimie des Substances Naturelles et Chimie Organique Biologique, Faculté des Sciences, Université d'Antananarivo, BP. 906, 101 Antananarivo, Madagascar
[3]Laboratoire de Chimie Minérale, Faculté des Sciences, Université d'Antananarivo, BP. 906, 101 Antananarivo, Madagascar

ABSTRACT

The aim of this study is to model thermodynamically isotherms of extraction in aqueous and hydroalcoholic media of Psiadia altissima (Asteraceae), to know the most adapted method of extraction to the powder structures of plant. In this study, water and 20% alcohol are used as solvents. Several series of experiments were carried out in order to obtain experimental results. Data are processed by Kaleidagraph and Maple software. Isotherms obtained are of type II, they can also present an hysteresis of H3 or H4 type, which shows that the powders of plant has an no uniform structure. The extractions can be comparable with an assembly of the models of Langmuir and Freundlich or Jovanovic and Freundlich. Agitation is necessary because of interactions between solutes on the multi-layer one. Concentration of solutions during the cold extraction is high. It is thus enough to carry out the operation by maceration.

Keywords: - *modeling, thermodynamics, extraction, isotherm, Psiadia altissima*

1. Introduction

Solid-liquid extraction is a fundamental operation of material transfer in a solid phase by a liquid solvent. Its purpose is to extract using a solvent, to separate and dissolve one or more solid or liquid components called solutes, mixed with a solid [1]. Different methods can be applied in solid-liquid extraction. The most common methods are decoction, infusion, percolation, maceration, digestion and elution [1-3]. The performance of an extraction depends on the state of the solute, the solvent and the solid. But other parameters such as agitation, temperature, humidity can also influence it [2, 4]. Solid-liquid extraction process is a very old operating technique. But it continues to interest researchers [5, 6]. Many methods have been proposed to improve this extraction technique; modeling is one of them. Many models exist but what interests us in this study is the extraction isotherm which is considered as a desorption [2]. The mechanism of extraction from plants is often neglected, but understanding it would improve extraction techniques. Moreover, many traditional Malagasy plants are not yet exploited, yet they offer significant economic potential. Such is the case of dingadingana with the scientific name *Psiadia altissima*. This plant is an endemic shrub of Madagascar. The extracts of this plant are used in traditional Malagasy medicine. They can fight against parasitic skin diseases and inflammatory tumor called boil or even as insecticides [7].
Thus, the objective of this work is to thermodynamically model the desorption of water-soluble and soluble solutes in hydroethanolic solvent, in order to know the structure of a solid containing the solutes to be extracted and

---

* Corresponding author. Tel : +261 34 12 634 55
e-mail address :rakotondramasy@yahoo.fr

especially the molecular structure with the possible interactions. The information from the model could help to choose the suitable thermodynamic parameters during a solid-liquid extraction operation. This step is essential in the industrial exploitation of a plant whose water-soluble extract is generally marketed.

2. Materials and methods

2.1 Plant material

Psiadia altissima was harvested around 9 a.m. at the beginning of October 2018. The harvest was made around the rural commune of Alasora, Analamanga region. The aerial parts of the plant are cut with secateurs and picked in a jute bag. They were then dried in a ventilated place, away from sunlight and humidity for at least 20 days. The dry plant materials were cut into small pieces and crushed in a mortar using a pestle. The powders obtained are sifted with a kitchen sieve to separate the large pieces from the fine powders.

2.2 Extraction

For a series of experiments, 20 extraction isotherm tests were carried out in 20 Erlenmeyer flasks containing 50 mL of solvent. Different masses of plant powder to be extracted noted (0.25; 0.50; 0.75; 1.00; 1.25; 1.50; 1.75; 2.0; 2.25; 2.50; 2.75; 3.00; 3.25; 3.50; 3.75; 4.00; 4.25; 4.50; 4.75; 5.00) are weighed using a balance Sartorius type L220S- *F2 precision . Then they are introduced respectively into the containers numbered from 1 to 20. The plant/solvent mixtures are placed on hot plates fitted with a magnetic stirrer. Stirring is ensured by a magnetic bar for 3 hours at room temperature. Two different solvents were used: water and a water/ethanol mixture, 80/20, v/v.

After 3 hours of extraction, each solution is filtered through absorbent cotton with a glass funnel. The residue is washed in 10 mL of solvent. Volume and mass of filtrate are measured respectively with a graduated cylinder and a Sartorius balance. Filtered solutions are transferred to a 500 mL flask, and then concentrated using a Janke and Kunkel IKA'Labortechnik RV-06ML rotary evaporator, at a temperature of 80°C. When the solution becomes quite concentrated, it is transferred to a crystallizer, and then placed in a moderately heated oven until it dries completely.

The dry product obtained, called extract, is weighed using a Sartorius precision balance, with the crystallizer. The weighing is repeated several times until a constant mass is obtained. The total mass of the crystallizer and the extract is noted. The mass of the extract is the difference between the total mass and the mass of the empty crystallizer. All these operations were repeated at least twice.

2.3 Isotherm

Isotherm is a diagram established at constant temperature. In this study, isotherms are curves representing the quantity extracted at equilibrium as a function of the solution concentration at equilibrium established at room temperature. To plot these isotherms, C_e is calculated with equation 1.

$$C_e = \frac{q_e}{V_S} \qquad \text{(Equation 1)}$$

where C_e (mg.L^{-1}) is the concentration at equilibrium, q_e (mg), the quantity extracted at equilibrium and V_S (mL), the volume of the solution.

2.4 Modeling

To model the obtained isotherms, they must be compared with isotherms proposed according to IUPAC classification [8] or the classification of Giles *et al.* [9]. It is necessary to analyze the slopes of each isotherm from the beginning of the curve to the end and also to identify if it possibly presents a hysteresis. After observation, the type of isotherm and the corresponding model can be proposed. Isotherm modeling is done using Kaleidagraph followed by Maple software. Three models are proposed to model isotherms: Langmuir, Jovanovic and Freundlich models.

2.4.1 Langmuir

Langmuir model is an equation that relates the quantity extracted at equilibrium as a function of the concentration at equilibrium with two other constant parameters (Equation 2).

$$q_e = \frac{q_m K_L C_e}{1 + K_L C_e} \qquad \text{(Equation 2)}$$

This model is used when the adsorbed solute site is well localized and each solute binds to a single site. It is an adsorption on the uniform surface whose adsorption energy of all the sites is identical. The extraction is done on a monolayer and there is no lateral interaction between the adsorbed solutes [10, 11].

Solving Langmuir equation is performed by linearizing Equation 1 which leads to Equation 3.

$$\frac{C_e}{q_e} = \frac{1}{q_m . K_L} + \frac{C_e}{q_m} \qquad \text{(Equation 3)}$$

Values obtained with linearization method are adjusted with Kaleidagraph software.

2.4.2 Jovanovic

Jovanovic model is an equation that relates the quantity extracted at equilibrium and the concentration at equilibrium and contains two constant parameters and (Equation 4) [12].

$$q_e = q_m . (1 - e^{-KC_e}) \qquad \text{(Equation 4)}$$

Where q_m (mg) is the maximum desorption capacity, q_e (mg) is the equilibrium extracted quantity, C_e (mg.L^{-1}), the solution equilibrium concentration and K, the Jovanovic constant.

This model represents a monolayer adsorption on the homogeneous surface. Mechanical contact between adsorbed and desorbed molecules is possible.

2.4.3 Freundlich

Freundlich model is presented in equation 5. This equation shows a relationship between the quantity extracted at equilibrium and the concentration at equilibrium with a constant parameter.

$$q_e = K_F . C_e^{1/n_F} \qquad \text{(Equation 5)}$$

Where q_e (mg) is the equilibrium extracted quantity, C_e (mg.L^{-1}), the solution equilibrium concentration, K_F (g$^{1-(1/nF)}$ .mL$^{1/nF}$) is the Freundlich constant which indicates the adsorption capacity of the adsorbent and n_F, the empirical constant related to the magnitude of the adsorption driving force.

Freundlich isotherm model is characterized by desorption at localized sites. In this case, interactions between adsorbed molecules are possible. This model applies for adsorption on a multilayer and porous site. It is represented by the two parameters K_F and n_F. Constants are determined experimentally by plotting the linear form of the equation as a function of (Equation 6) [12-14].

$$\ln q_e = \ln K_F + \frac{1}{n_F} . \ln C_e \qquad \text{(Equation 6)}$$

After linearizing this equation, the values of K_F and n_F are obtained. These values are adjusted with Kaleidagraph software.

3. Results and discussions

3.1 *Extraction and isotherm*

20 masses of extracts and crystallizers m_T (g) are obtained by weighing for each series of extraction. Difference between m_T and the mass of each vacuum crystallizer m_C gives the amount extracted at equilibrium q_e. When q_e and V_S are known, the equilibrium concentrations C_e are determined.

Table 1 present results in aqueous medium.

Table -1: Extraction results in aqueous medium

N°	$m_P(g)$	$V_S(mL)$	$m_T(g)$	$m_C(g)$	$q_e(g)$	$C_e(mg.mL^{-1})$
1	0.25	58.5	22.506	22.425	0.081	1.384
2	0.50	58	22.080	21.949	0.131	2.258
3	0.75	58.5	21.776	21.569	0.207	3.538
4	1.00	55	20.989	20.645	0.344	6.254
5	1.25	48	22.457	22.070	0.387	8.062
6	1.50	50.41	18.213	17.779	0.434	8.609
7	1.75	54	18.218	17.589	0.629	11.648
8	2.00	55	20.143	19.587	0.556	10.109
9	2.25	54	18.675	17.906	0.769	14.240
10	2.50	52.5	19.178	18.480	0.698	13.295
11	2.75	52.5	19.242	18.494	0.748	14.247
12	3.00	42.5	21.420	20.381	0.859	20.212
13	3.25	54	26.050	25.005	1.045	19.352
14	3.50	52.5	38.142	37.165	0.977	18.609
15	3.75	52.5	41.428	40.165	1.263	24.057
16	4.00	42.5	32.577	31.521	1.056	24.847
17	4.25	51	25.166	24.020	1.146	22.470
18	4.50	52.5	24.069	22.671	1.398	26.628
19	4.75	52	22.602	21.351	1.251	24.057
20	5.00	48	25.402	23.965	1.437	29.937

Table 2 present results in hydroethanolic medium.
Table -2: Extraction results in ethanol 20% medium

N°	$m_P(g)$	$V_S(mL)$	$m_T(g)$	$m_C(g)$	$q_e(g)$	$C_e(mg.mL^{-1})$
1	0.25	47	24.082	23.965	0.117	2.489
2	0.50	47	21.568	21.351	0.217	4.617
3	0.75	51.50	22.957	22.671	0.286	5.553
4	1.00	50	24.269	24.02	0.249	4.980
5	1.25	48	31.88	31.521	0.359	7.4792
6	1.50	47	40.514	40.165	0.349	7.425
7	1.75	46.5	37.66	37.165	0.495	10.645
8	2.00	44	25.645	25.005	0.64	14.545
9	2.25	47	20.951	20.381	0.57	12.127
10	2.50	50	19.167	18.494	0.673	13.460
11	2.75	54	19.218	18.48	0.738	13.667
12	3.00	52	18.774	17.906	0.868	16.692
13	3.25	45	20.474	19.587	0.887	19.711
14	3.50	40	18.75	17.589	1.161	29.025
15	3.75	51	18.794	17.779	1.015	19.902
16	4.00	53.5	23.124	22.07	1.054	19.701
17	4.25	44	21.805	20.645	1.16	26.363
18	4.50	45	22.622	21.569	1.053	23.400
19	4.75	48.5	23.163	21.949	1.214	25.031
20	5.00	42	23.692	22.425	1.267	30.167

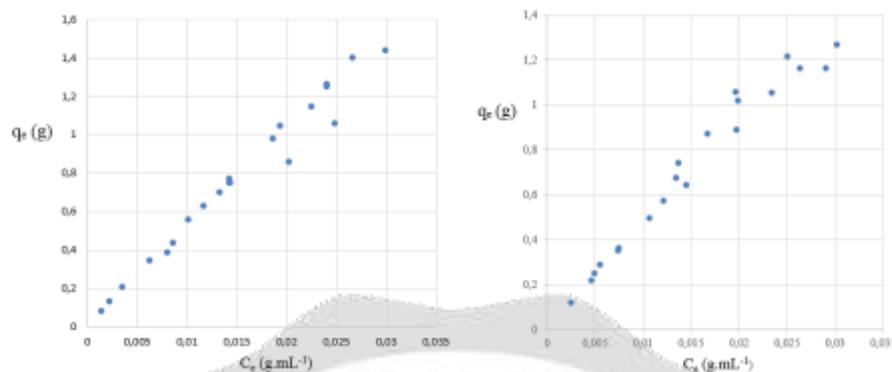Isotherms in both media are plotted in chart 1.

Chart -1: Extraction isotherms of *Psiadia altissima* solutes with water (left) and ethanol 20% (right)

Chart 1shows that the first experience point corresponds to a higher concentration with ethanol 20% than that obtained with water. The experimental points increase steadily with the concentration at equilibrium, but from the point coordinates (C_e=0.013 g.mL^{-1} and q_e = 0.6 g), a dispersion of the points can be observed. The extraction isotherm can give two curves. The first corresponds to the 14 points which increase regularly with the concentration at equilibrium (Experiments n°: 1, 2, 3, 4, 5, 6, 7, 8, 9, 13, 14, 17, 18, 20) and the second is by the 4 aligned points located above the first curve (Experiments n°: 11,12, 15,19).

By comparing the two models according to the solvent used, changing the solvent to 20% ethanol makes it possible to have a high quantity of extracts at the start of desorption (first 3 points). But, the opposite is observed at the end of the extraction.

3.2 Modeling

Isotherms modeling are based on the two types of curve. The lower slope curve is considered as the main curve while the other, higher slope is a secondary curve which determines the hysteresis. Three models are tested: Langmuir, Jovanovic and Freundlich model.

3.2.1 Langmuir model

Extraction with water

Langmuir constants K_L and q_m are known after linearization (Table 3).

Table -3: Langmuir parameters obtained by linearization method for aqueous extraction

	main curve	secondary curve
$K_L(mL.g^{-1})$	51.6	42.81
$q_m(g)$	8.65	13.37
R²	0.595	0.365

In order to determine the model corresponding to each curve, values obtained by linearization were introduced into the Kaleidagraph software to improve the resolution (Table 4).

Table -4: Langmuir parameters obtained by fitting linearized parameters by Kaleidagraph for aqueous extraction

	main curve	secondary curve
$K_L(mL.g^{-1})$	14.164±2.78	4.03±1.462
$q_m(g)$	3.98±0.618	13.965±4.662
R²	0.997	0.996

In this case, the correlation coefficients R² are improved and high for both curves. The two new Langmuir models are then gathered on the Maple software using the statistical values of K_L and q_m, obtained by Kaleidagraph (Equation 7).

$$q_e = \begin{cases} \dfrac{3.98 \times 14.164 \times C_e}{1 + 14.164 \times C_e} \\ \dfrac{13.965 \times 4.03 \times C_e}{1 + 4.03 \times C_e} \end{cases} \qquad \text{(Equation 7)}$$
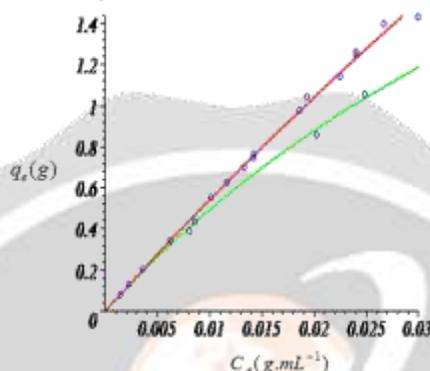
The graphical representation of equation 7 is given in chart 2.

Chart -2: Comparison between experimental and modeled extraction isotherms of *Psiadia altissima* solutes in water using Langmuir model

In this case, it is the assembly of the two single-layer and non-porous models. The plots of the two models are initially confounded, but they are separated when the concentration is high. This means that this model can be divided into two parts. The common part can correspond to an extraction isotherm on a monolayer and the separated part on a multilayer. Therefore, the isotherm can be presented with hysteresis of type H3 or H4. Here, the upper part of a hysteresis is not marked because of insufficient experimental points.

Extraction with ethanol 20%

The same methods are applied to model the extraction in a hydroethanolic medium. Then, Langmuir constants K_L and q_m are known after linearization (Table 5).

Table -5: Langmuir parameters obtained by linearization method for hydroethanolic extraction

	main curve	secondary curve
$K_L(\text{mL.g}^{-1})$	42.2	56.53
$q_m(g)$	7.82	5.58
R²	0.737	0.99

Values obtained by linearization were introduced into the Kaleidagraph software to improve the resolution (Table 6).

Table -6: Langmuir parameters obtained by fitting linearized parameters by Kaleidagraph for hydroethanolic extraction

	main curve	secondary curve
$K_L(\text{mL.g}^{-1})$	7.210 ± 1.628	19.864±7.65
$q_m(g)$	7.047 ± 1.364	3.543±0.978
R²	0.996	0.983

As before, coefficientsR² have become higher for both curves which indicates that the Langmuir model can present the process phenomena. The two equations corresponding to the two curves were introduced in the Maple software to form only one (equation 8).

$$q_e = \begin{cases} \dfrac{7.047 \times 7.21 \times C_e}{1 + 7.21 \times C_e} \\ \dfrac{3.543 \times 19.864 \times C_e}{1 + 19.864 \times C_e} \end{cases} \qquad \text{(Equation 8)}$$

After data processing, the plots of the model with the experimental points are shown in chart 3.
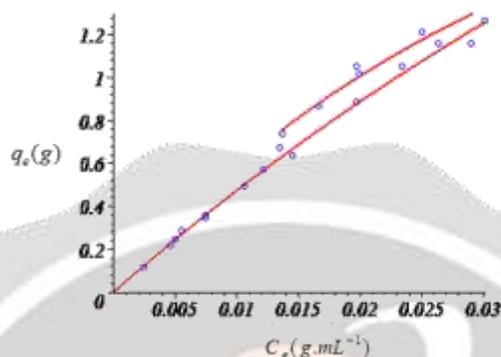

Chart -3: Comparison between experimental and modeled extraction isotherms of *Psiadia altissima* solutes in ethanol 20% using Langmuir model

In this case, two monolayer models are put together. The second pattern begins when the concentration reaches 0.013 g.mL^{-1}. They are well separated, but can give another pattern. As in the case of extraction with water, this pattern can be divided into two parts. At a concentration lower than 0.013 g.mL^{-1}, the isotherm may resemble an extraction on a monolayer. And when this concentration is reached, the isotherm can correspond to an extraction on a multilayer and can be presented a hysteresis of type H3 or H4.

3.2.2 Jovanovic model

The Jovanovic model is a nonlinear equation. Therefore, the linear regression method is not valid. Adjustment of the values is therefore done by reasoning in relation to the results of Langmuir until obtaining a maximum correlation coefficient

Extraction with water

Jovanovic constants K_L and q_m are known after direct data processing with Kaleidagraph (Table 7).

Table -7: Jovanovic parameters obtained by Kaleidagraph for aqueous extraction

	main curve	secondary curve
K_L (mL.g^{-1})	12.346 ± 2.950	24.568 ± 4.492
q_m (g)	4.774 ± 0.996	2.267 ± 0.325
R²	0.995	0.997

The correlation coefficients are very high. The combination of these models by the Maple software leads to obtaining the isotherm model of extraction of water-soluble solutes in *Psiadia altissima*. Experimental points and models correlate perfectly (chart 4).
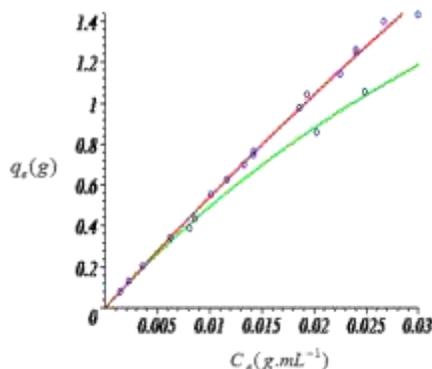
Chart -4: Comparison between experimental and modeled extraction isotherms of *Psiadia altissima* solutes in water using Jovanovic model

Model obtained by the Jovanovic model is identical to the result of the model by Langmuir. Like the previous analysis, the extraction isotherm with water can present an H3 or H4 type hysteresis or consider as desorption on a multilayer followed by a monolayer.

Extraction with ethanol 20%

The same method was applied for ethanolic solvent, Jovanovic constants K_L and q_m are given in table 8..

Table -8: Jovanovic parameters obtained by Kaleidagraph for ethanolic 20% extraction

	main curve	secondary curve
$K_L (mL.g^{-1})$	3.805 ± 0.667	3.612 ± 2.042
$q_m (g)$	13.303 ± 2.734	12.482 ± 7.501
R²	0.996	0.999

As for aqueous extraction modelling, the correlation coefficients are very high too in this case. Jovanovic model can be correlated with the process phenomena. These models are combined by Maple software and experimental points and models are correlated (chart 5).
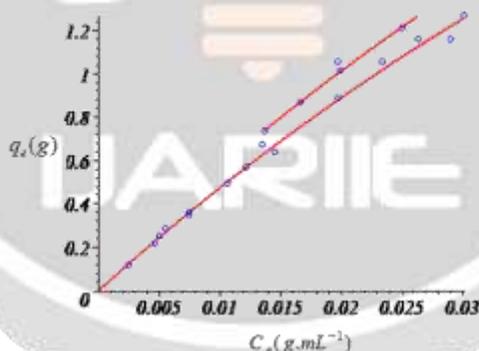

Chart -5: Comparison between experimental and modeled extraction isotherms of *Psiadia altissima* solutes in ethanol 20% using Jovanovic model

Assembly of these two curves makes it possible to say that it is an extraction on a multilayer followed by a monolayer, which corresponds to a type II isotherm. This curve can also present an H3 or H4 type hysteresis.

3.2.1 Freundlich model

Extraction with water

Freundlich constants K_F and n_F are known after linearization (Table 9).

Table -9: Freundlich parameters obtained by linearization method for aqueous extraction

	main curve	secondary curve
n_F	0.875	0.956
$K_F(g^{1-(1/n_F)}.mL^{1/n_F})$	0.023	0.387
R²	0.9972	0.997

To improve the resolution, these values are using for Kaleidagrapg direct processing data (Table 10).

Table -10:Freundlich parameters obtained by fitting linearized parameters by Kaleidagraph for ethanolic extraction

	main curve	secondary curve
n_F	1.181±0.025	1.059±0.025
$K_F(g^{1-(1/n_F)}.mL^{1/n_F})$	23.826±1.733 10^{-3}	41.653±3.712 10^{-3}
R²	0.998	0.995

The method is followed by processing data with maple software et combine the curves (equation 9)

$$q_e = \begin{cases} 23.826 \times C_e^{1/1.181} \\ 41.653 \times C_e^{1/1.059} \end{cases}$$ (Equation 9)

The chart 6 shows the correlation between experimental point and model are correlated.
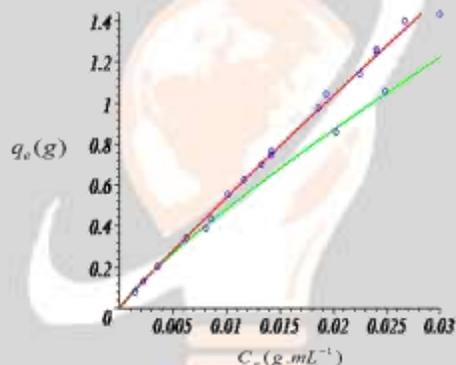
Chart -6: Comparison between experimental and modeled extraction isotherms of *Psiadia altissima* solutes in water using Freunclich model

The model obtained with the Freundlich model is globally identical to that of Langmuir. At low concentration, the two curves obtained by Kaleidagraph are confused and they are distinguished when the concentration is high. The model of this curve can then be suitable for the isotherm of type II or present a hysteresis of type H3 or H4.

Extraction with ethanol 20%

Freundlich constants K_F and n_F are known after linearization (Table 11).

Table -11: Freundlich parameters obtained by linearization method for ethanolic extraction

	main curve	secondary curve
n_F	0.937	0.83
$K_F(g^{1-(1/n_F)}.mL^{1/n_F})$	0.023	0.02
R²	0.997	0.999

To improve the resolution, these values are using for Kaleidagraph direct processing data (Table 12).

Table -12:Freundlich parameters obtained by fitting linearized parameters by Kaleidagraph for ethanolic extraction

	main curve	secondary curve
n_F	1.110±0.028	1.442±0.020
$K_F(g^{1-(1/n_F)}.mL^{1/n_F})$	29.722±2.605 10^{-3}	15.111±5.727 10^{-3}
R²	0.995	0.973

There is no real difference between linearization and direct processing data for resolution of Freundlich models. The method is followed by processing data with maple software (equation 7)

$$q_e = \begin{cases} 29.722 \times C_e^{1/1.11} \\ 15.111 \times C_e^{1/1.442} \end{cases} \qquad \text{(Equation 7)}$$

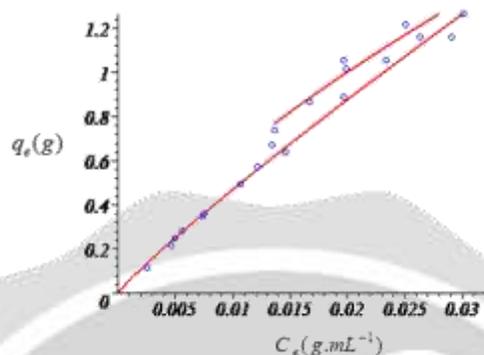The chart 7 shows the correlation between experimental point and model are correlated.

Chart -7: Comparison between experimental and modeled extraction isotherms of *Psiadia altissima* solutes in ethanol 20% using Freundlich model

As in the case of the extraction with water, the results of the test with the model of Freundlich and Langmuir are identical.

3.3 Interpretation

According to the three tests of the model, Langmuir, Jovanovic and Freundlich, it is observed that the three models correlate with the experimental results. But, the presence of hysteresis demonstrates the presence of multilayer and pore in the form of a slit. Thus, Freundlich model is preferred. However, in the first part, that is to say at a concentration lower than 0.013 g.mL^{-1}considered common to the two curves, it can be assumed that it is a monolayer. Thus, Langmuir or Jovanovic model is privileged.

Furthermore, we can also assume that the main curve (bottom) can be composed of a superposition of two curves, one of which represents a Langmuir or Jovanovic model and the other a Freundlich model. as much monolayer as multilayer of solutes in the plant. The Langmuir or Jovanovic model corresponds to an extraction of solutes in monolayer form on the homogeneous surface and the Freundlich model to an extraction on the multilayer of solutes with a porous surface. If the isotherm presents a hysteresis of the H3 or H4 type, it corresponds to an extraction of the solutes in a porous solid in the form of a slit.

Three hypotheses are then proposed:

- The extraction may look like a combination of the two models: Langmuir-Freundlich or Jovanovic-Freundlich. That is to say, the common part of the curve may correspond to an extraction of solutes in monolayer form at the surface of the solid, which may be due to washing. And the separated part corresponds to an extraction of solutes in multilayer form in the presence of mesopores because this is what causes hysteresis and solutes in monolayer form.
- The extraction can also look like a combination of the two models: Langmuir-Freundlich or Jovanovic-Freundlich. That is to say, the common part of the curve may correspond to an extraction of solutes in monolayer form at the surface of the solid, which may be due to washing. But, the separated part corresponds to an extraction of solutes in multilayer form in the presence of mesopores because this is what causes hysteresis and solutes on the first layer of multilayers.
- The extraction can always correspond to the two models: Langmuir-Freundlich or Jovanovic-Freundlich. But, the physical characteristics of the solid are not identical to the first and second hypothesis. The common part of the curve may look like an extraction of solutes in monolayer form and the separated part corresponds to an extraction of solutes in a porous solid with different pore sizes.

In these three hypotheses, the plant has a non-uniform structure which can be divided into two parts, an internal part formed of micropore or mesopore and an external part presenting no pore, that is to say the external surface of the solid.

Generally, in a solid-liquid extraction, the determining factors during diffusion are viscosity and agitation. Thus, the less viscous the solvent, the higher its rate of diffusion towards the interior of the solid. 20% ethanol is less viscous

than water, so it must be more favorable to extraction. This can explain the exceptions in a very dilute medium, but this viscosity can change with more concentrated solutions because the initial viscosities are not very different. Heating the solution can improve the diffusion of solutes located in the pores. Methods using medium temperature such as digestion and infusion can be proposed. However, since the solutions obtained during cold extraction are concentrated and according to model data, the potentials for interactions between the solutes and plant walls are weak, so the use of maceration as an extraction method is sufficient to extract water-soluble and 20% ethanol-soluble solutes from *Psiadia altissima*. This method has the advantage of being profitable both economically and energetically.

4. CONCLUSIONS

The purpose of this study is to determine and model the isotherms of extractions of water-soluble and hydroalcoholic solutes of *Psiadia altissima*, to know the appropriate extraction methods. Information on the results of isotherms can define the physical characteristics of *Psiadia altissima* and the transfer of solute from a solid phase of plant origin to the liquid solvent. The knowledge of these physical characteristics is interesting for the choice of the extraction method to be used. According to the results, the addition of ethanol does not improve the extraction yields except during extractions in a very dilute medium (first 3 points). Indeed, the models have shown that the polar solutes do not have a high potential for interaction with the walls of the plant, so they are easily extractable with water. The isotherms of extractions obtained show that *Psiadia altissima* has a non-uniform structure. The inner part can be formed of micropores or mesopores while the outer part has no pores. The correlation coefficients of the Langmuir, Jovanovic and Freundlich model are almost maximal. These results confirm that the extraction isotherms correspond to an IUPAC type II with an H3 or H4 type hysteresis. This allows us to say that the extraction begins with a multilayer followed by a monolayer. In this case, there is no interaction between solutes on a monolayer. On the other hand, these interactions are possible on a multilayer. Agitation during extraction is therefore necessary. Here, water and ethanol are particularly polar solvents; they are able to extract polar solutes. Generally, the concentrations of the extracted solutions obtained by the two solvents during the extraction are high. Cold extraction such as maceration is therefore the most profitable economically and energetically.

In this study, the solutes obtained during the extraction are particularly polar solutes. However, if one wants to extract the nonpolar solutes from this plant, one would have to use methods that can break the interactions between the plant walls and the nonpolar solutes.

6. REFERENCES

[1]. B.Ben Amor, Maitrise de l'aptitude technologique de la matière végétale dans les opérations d'extraction de Principes actifs; texturation par détente instantanée controlée (DIC), Thèse de doctorat en Génie des Procédés Industriels, Université de la Rochelle, France, 2008.

[2]. R. Poirot, Méthodologie pour le passage en continu d'extraction de soluté à partir de matière végétale, Thèse de doctorat, Institut national polytechnique de Toulouse, 2007.

[3]. J. Leybros, P. Fremeaux Extraction solide-liquide - Aspects théoriques. Techniques de l'Ingénieur (traité Génie des procédés), J 2780, 1990.

[4]. L. Rakotondramasy-Rabesiaka, L. Rakotonirina, M. Rabesiaka, and A. Raharisololalao, Modeling of solid-liquid Extraction of Water-solubles from *Salvia coccinea* (Lamiacea), International Journal Of Advance Research And Innovative Ideas In Education, 7(5)2021 : 1123-1132.

[5]. L. Rakotondramasy-Rabesiaka, M. Randrianarijaona, A. Raharisololalao, M. Rabesiaka. Study of the solid-liquid extraction from two plants, *Salvia coccinea* (Lamiaceae) and *Syzygium sakalavarum* (Myrtaceae) : modelling of isotherm, International Journal of Advance Research and Innovative Ideas in Education 2021, 5(7) 2021: 1417-1428.

[6]. L. Rakotondramasy-Rabesiaka, J.-L. Havet, C. Porte, H.Fauduet, Solid-liquid extraction of protopine from Fumaria officinalis L. – Kinetic modelling of influential parameters, Ind. Crops. Prod. 29 (2009) 516-523.

[7].P.A.R. Ramanoelina, J.R.E. Rasoarahona, V. Masotti, ,J. Viano, E.M. Gaydou, J.-P. Bianchini Chemical Composition of the Leaf oil of *Psiadia altissima* (Compositae), Journal of Essential Oil research, 6, 1994 : 565-570.

[8]. M.-R. Babaa, Contribution à l'étude de l'adsorption physique de gaz sur les nanotubes de carbone mono et multiparois, Thèse, Université Henri Poincaré, Nancy-I en Physique et Chimie de la Matière et des Matériaux, 2004.

[9]. A. Hamouche, Etude cinétique et thermodynamique de l'adsorption des métaux lourds par l'utilisation des adsorbants naturels, Thèse de doctorat, Université M'hamed Bougara-Boumerdes, 2013.

[10]. Y.Liu, L.Shen, From langmuir kinetics to first- and second-order rate equations for adsorption, Langmuir 24, 2008.

[11]. N.J. Krou, Etude expérimentale et modélisation d'un procédé séquentiel AD-OX d'élimination de polluants organiques, Thèse de doctorat, Université de Toulouse, 2010,.

[12]. I. Quinones, G. Guiochon, Extesion of a Jovanovic-Freundlich isotherm model to multicomponent adsorption on heterogeneous surfaces, J. Chromato. A 796(1)1998: 15-40.

[13] R.Ezzati, Derivation of pseudo-first-order, pseudo-second-order and modified pseudo-first-order rate equations from Langmuir and Freundlich isotherms for adsorption, Chemical Engineering. Jounal 392, 2020: 123705.

[14]J. Toth, Adsorption, theory, modeling and analysis, Edition Babel New York, 2002.