Chemical Evolution of Solutions from Beans Soaking and Cooking Processes: Case Study of Phaseolus Vulgaris L.

By J. C. Fopoussi Tuebue & I. N. Tchinda

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Keywords: waste water, sanitation, recycling, fertilization, agriculture, nutrition, temperature.

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I. Introduction

From the onset of the nineteenth century, like swarms of bees, springing from fountain pens of thinkers, disturbing facts with increasing intensities aggregated. These are facts, as different as day and night and numerous like grains of sand on a beach, which reflect the occurrence of the multifaceted links that exist between the food consumed and the state of health of the consumer. In this sense, the better the quality and composition of the food, the better the health of the consumer, and vice versa [1]. The quality of a food is commonly seen as being the consequence of a more or less adequate state of conservation of the given material [2]. Regarding its composition, it is linked either to the nature of the food [3] or to the modification that the food has undergone during handling [4]. Therefore, the limit between the causes of malnutrition and good nutrition becomes a little more difficult to define because we are in the presence of a multifactorial scourge [5]. Contributing to better nutrition among a people then comes down to carefully scrutinizing all the practices linked to this biological function. When we talk about nutrition, we are referring to the set of processes by which a living being transforms food to ensure its survival [6]. Regarding humans, the great variety of food resources has logically led to highly varied diets [7]. Thus, while some people will adopt simple diets, others will adopt rather complex diets [8]. Regarding the type of food consumed by humans, we will distinguish some that are eaten raw and others that necessarily require the cooking phase [9]. From an essentially dietary perspective, the specialists in the field increasingly recommend the consumption of at least one fruit per day. It is indeed the undisputed source of vitamins for the body, the vast majority of these first-degree functional nutrients being heat labile [10]. Such a prescription, carried out daily with insistence and authority, is very quickly found on the front line as generating many questions in the minds of the informed man. One might therefore be tempted to ask the question whether the vitamin concentration in cooked foods is the only one to change during the cooking process. It is undoubtedly in this sense that [11] undertook to test, fortunately for scientific research, with success, the water at the end of cooking beans on

strongly desaturated and very strongly acid soils as a potential way towards soils fertility recovery. Observations from these trials subsequently led [12] to also successfully test the mixture of end-of-cooking solutions from beans and human urine on plant growth. If in the first case there were significant improvements in the chemical fertility parameters of the soils involved, the characterization of the end-of-cooking solution of the beans remained only embryonic, thus helping to keep a heavy veil on the deeper knowledge of this fluid. In the context of this study, it is therefore a question of returning to the shortcomings of the work of [11] and [12] in order to try to shed light on the real composition of solutions at the end of cooking and soaking the beans, pledge of a strong advance in Science in the management of what one might be tempted to call "kitchen waste". This will be done in reference to the chemical changes undergone by the food during the processes mentioned. It will be in detail a question of specifying and quantifying the elements lost when food products enter the cooking phase on the one hand and the soaking phase on the other hand. In accordance with the principles of the inferential approach as recommended by [13], these losses will be assessed by progressive monitoring of the composition of the cooking water and of the soaking respectively. For this, the beans, because of its compulsory passage through the cooking phase and optional through the soaking phase was retained. The choice of this plant species is linked to the fact that it is one of the foods not only abundantly produced, but also appreciated in Cameroon [14]. From this large group, "Meringue", one of the main representatives of the *Phaseolus vulgaris L.* species, was chosen.

II. MATERIALS AND METHODS

a) Materials

i. Bean seeds

Most of the African population is engaged in agriculture ([15], [16], [17]). Among the main cultivars, we have the bean [18]. This food is very popular throughout Cameroon because of its flavor and its dietary potential ([19], [20], [21]). For 100g of this food, there are organic compounds such as proteins (9.06g), carbohydrates (27.91g), lipids (0.49g), fibers (5.3g); water (61.2g); varieties of vitamins including vitamins B1 or thiamine (0.257mg), B2 or riboflavin (0.063mg), B3 / PP or niacin (0.57mg), B5 or pantothenic acid (0.299mg), B6 (0.175mg), E or tocopherol (0.98mg), K (3.7µg); total folate (168µg); many mineral elements including potassium (508mg), sulfur (225mg), phosphorus (165mg), magnesium (65mg), calcium (52mg), iron (2.3mg), sodium (2mg), zinc (0.96mg), manganese (0.548mg), copper (0.271mg), selenium (1.4µg) ([22], [23], [24], [25]). The total nitrogen content (1450mg) was deduced from the protein content by applying the Jones factor [26] according to which protein content = total nitrogen * 6.25.

About 85% of dry beans are consumed in some of the countries where they are grown. The remaining 15% are marketed ([27]). In the case of Cameroon, importation is almost absent. Large quantities are produced, but the bulk is for export ([28]).

The flatulent effect of beans is universally known and has, undoubtedly, been a source of discomfort throughout history [29].

ii. Solution from cooked beans

Solution from cooked beans is aheterogeneous mixture, and particularly a proteicglobular suspension, with considerable amounts of carbohydrates within. It has a pH value of 6.4. At rest, that fluid divides itself into two superimposed domains: a flaky superficial domain and a liquid lower domain. The flaky domain is the organic part and theliquid domain is the water and the mineral salts provider. The density of the flaky domain is 0.964and that of the liquid domain is 1.011. The average speed of the growth of *Aspergillus L.* at the surface of the water from cooked beans is3, 17 cm^2/H; they cover in five days a surface of379.74 cm^2.The physic-chemical characteristics of the flaky domain floating on the liquid domain make it an adequate area for the development of molds (*Aspergillus L.*). Solution from cooked beans Seems then to contain all the nutrients required for an optimal development of those beings (*Aspergillus L.*), and in the same way for anoptimal fertilization of soils; this include water, organic matters and mineral salts among which nitrogen, potassium, phosphorus, sulfur and calcium can be named. It is then a complete liquid organic fertilizer. That solution positions itself also as a high grade activator for soils microflora. It represents finally a way for a sustainable improvement of agriculture in developing countries and a way for a sustainable development of soils micro flora, required for the reach of the food self-sufficiency. Solution from cooked beans is finally not only a source of nutrients for plants, but it also positions itself as a high grade activator for soils micro flora [13].

b) Methods

To achieve the fixed objectives, the work was carried out in the field and in the laboratory.

i. In the Field

In the field, it was a question of obtaining the beans necessary for the production of the end-of-cooking solution for this food. The variety purchased is "Meringue" (photograph 1), one of the representatives of the species *Phaseolus vulgaris L.* It was also a question of getting closer to the families to question them in relation to the actions they take during the preparation of the bean-based meal. In total, between September 2019 and December 2019, 500 families were interviewed, i.e. 50 families in each of the 10 regions of Cameroon.

Photograph 1: « Meringue »

ii. *In the laboratory*
a. *Handling of bean samples and preparation of water samples*

In the laboratory, the bean was sorted in order to remove the stones. Then followed the weighing phase at the end of which 2,000 g of beans were taken for testing. The sample was then quickly washed to remove dust and all forms of impurities, then soaked for 1 hour in 8 liters of water, or 1 mass of bean for 4 mass of water. In detail, we started on the basis that 1 liter of water weighs 1 kg according to [30]. During the soaking phase, two samples of the same amount of water were taken. The first setting was made thirty minutes after the start of the soak and the second setting 60 minutes after; after each intake, the amounts of water removed were replaced by water drawn for cooking. Just before placing the pot containing the soaked water-bean mixture on the fire, a gauge line was marked on the rim of the pot in order to keep the water level intact during cooking by regular addition of water provided for cooking. Three water samples of the same quantities were taken during the cooking phase: the first 30 minutes after the start of cooking, the second 60 minutes after the start of cooking, and the third 90 minutes after the start of cooking. After each setting, the cooking water was brought back to the mark by adding water provided for cooking. The collected waters were cooled, bottled and the bottles labeled. These samples were supplemented by a sample of water used for cooking as control. Has followed the analytical phase. It focused on pH, electrical conductivity (EC), Ca^{2+}, Mg^{2+}, K^+, Na^+, HPO_4^{2-}, SO_4^{2-}, NH_4^+, Cl^-, and HCO_3^-.

The IonPac CS12A and IonPac AS12A analytical columns were respectively used for the separation of ammonium ($NH4^+$), calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^+), and potassium (K^+) as far as cations were concerned, and chloride (Cl^-) and sulfate ($SO4^{2-}$) in the case of anions. The flow rate was set to 1.0 mL/min for both cations and anions optimization. The different cations were isocratically separated with a 20mM Methanesulfonic acid solution within 15 minutes. Concerning the ions studied here, isocratic elution with 4mM and 20mM Sodium hydroxide solution were employed for their separation, respectively for chloride and sulfate, during 15 minutes. All eluents were degassed and pressurized under high purity nitrogen to prevent dissolution of carbon dioxide and subsequent production of carbonate.

Concerning bicarbonate ion ($HCO3^{2-}$), its amount was measured by using titrimetric method. The pH was determined with a pH-meter having a glass electrode. Electric conductivity for its own was measured using a conductivity meter fitted with a calibrated measuring cell; the results were expressed in mS/cm.

b. *Determination of bean seeds mass loss*

In other to determine the mass loss by bean seeds during soaking and cooking processes, 1kg of beans was taken. From there, six batches of 100g beans were made. The first batch served as a control (mt or control mass = 100g). The other five batches were respectively washed quickly. The first batch of the five was soaked for 30 minutes, then dried (mht30cr = raw bean mass soaked for 30 minutes). The second batch was soaked for 60 minutes then dried (mht60cr = raw bean mass soaked for 60 minutes). The third batch was soaked for 60 minutes then cooked for 30 minutes and dried (mht60cu30 = bean mass soaked for 60 minutes and cooked for 30 minutes). The fourth batch was soaked for 60 minutes then cooked for 60 minutes and dried (mht60cu60 = bean mass soaked for 60 minutes and cooked for 60 minutes). The fifth batch was soaked for 60 minutes then cooked for 90 minutes and dried (mht60cu90 = bean mass soaked for 60 minutes and cooked for 90 minutes). In all five samples, drying was carried out in the open air until complete desiccation. To evaluate the mass losses (pm), we set respectively pm = mt- (mhtc)i. The percentage of material lost at each stage (pmpce) was obtained by setting pmpce = (pm / mt) * 100.

III. Results and Discussion

a) *Results*
i. *Field facts*

In Cameroon, beans are consumed in more than one form: boiled then fried, boiled then pounded, in the form of donuts, in the form of a cake, in the form of stew, boiled and then fried in mixture with boiled corn. Etc. By far, the most popular are the forms of cooking that integrate boiling in their cooking phases. The volume of water from cooking this cultivar is large, and increases with the amount of beans boiled.

To cook the beans, the populations, in general, sort, float, wash, soak, and boil. Regarding the trends in the use of end-of-cooking solution for beans (figure 1), 465 (93% of all) families (F1) throw end-of-cooking solution far from the habitat due to the subsequent odor induced. 15 (3% of all) families (F2) continue cooking with this water. 20 (4% of the whole) families (F3) cool this water and give it to their pigs to drink ...).
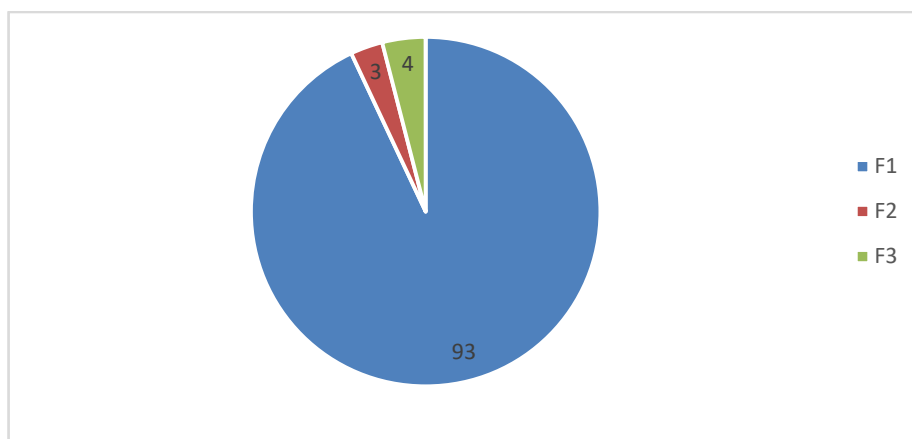
Figure 1: Managing the bean end-of-cooking water in Cameroon

Pig farmers who feed their animals with spent grain mixed with bean end-cooking solution justify their actions by the extraordinary results obtained. The families who continue to cook with this solutoin justify this act by an inheritance from their parents, who have regularly claimed that in doing so, we are better nourished. They do it as part of the preparation of the culinary dish called "pounded". For this, they use the solution from the boiling of the beans to cook what they will pound the beans with. The families who throw out the bean after cooking water justify their act by the fact that it is dirt. Indeed, they are based on the fact that when one comes to pour the water at the end of cooking around the house, shortly after, one notices the emanation of a strong odor which can only disappear after two or even three days depending on the amount of bean solution poured. It shows that the majority of the population at the end of the cooking process rejects as waste water the water from the end of cooking of the bean (Figure 1).

b) Analytical facts

All the parameters monitored within the framework of this study are on the rise despite local variations.

i. *Cations*

Among the cations, the decreasing order of concentration of the elements in the different solutions is as follows: $NH_4^+ > > > > K > > > Mg > Ca > > > > > Na$.

a. *Earth alkali cations*

There is a strong similarity in the behavior of calcium and magnesium when the seeds are either soaked or boiled. In fact, the calcium contents (Figure 2A and Table 1) are as follows: 0.0045g / l in the water used for cooking the seeds (E1), 0.046g / l after 30 minutes of soaking (E2) , 0.103 after 60 minutes of soaking (E3), 0.183g / l after 60 minutes of soaking and 30 minutes of cooking (E4), 0.321g / l after 60 minutes of soaking and 60 minutes of cooking (E5), and 0.403g / l after 60 minutes of soaking and 90 minutes of cooking (E6). Regarding magnesium (Figure 2B and Table 1), its contents change as follows: 0.0034g / l in the water used for cooking the seeds (E1), 0.062g / l after 30 minutes of soaking (E2), 0.138 after 60 minutes of soaking (E3), 0.244g / l after 60 minutes of soaking and 30 minutes of cooking (E4), 0.429g / l after 60 minutes of soaking and 60 minutes of cooking (E5), and 0.538g / l after 60 minutes of soaking and 90 minutes of cooking (E6). With the involvement of the temperature, the calcium and magnesium contents gradually and significantly increase during cooking to reach their maximum values at the end of the phenomenon. It can also be noted that between the thirtieth minutes and the sixtieth minutes of cooking, the respective content of these two elements tend to double before gradually increasing until the end of the cooking process.
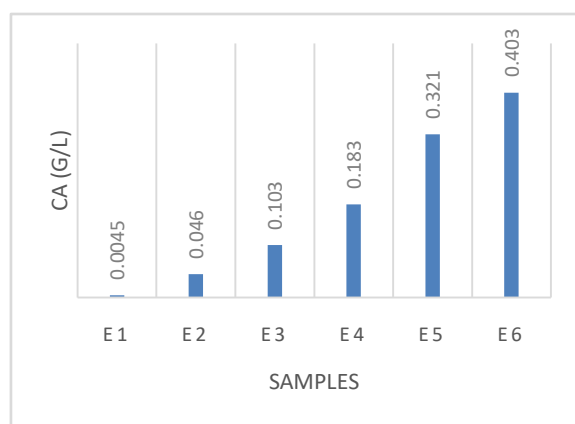
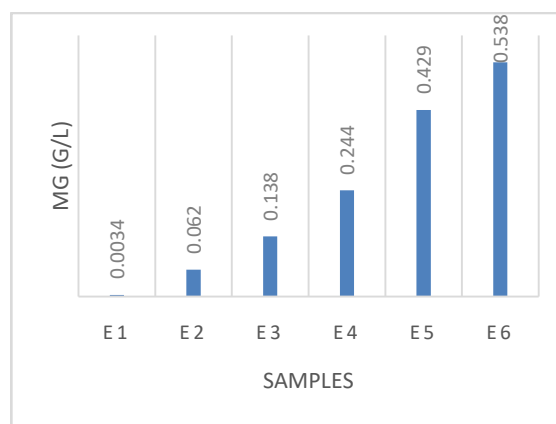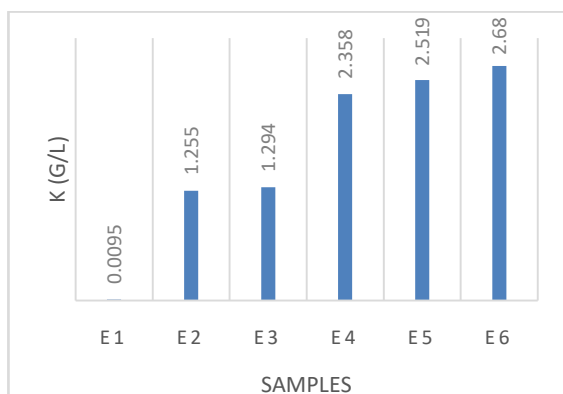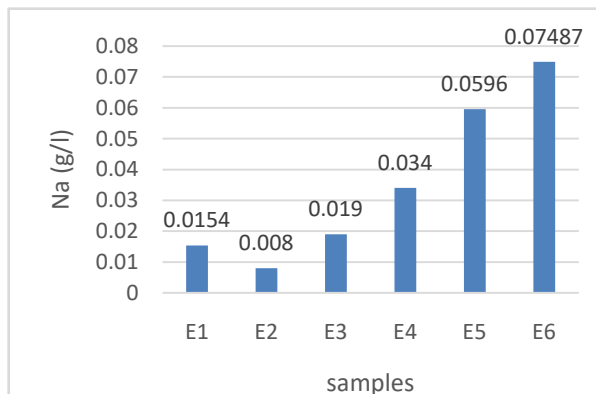Figure 2A: Evolution of the amounts of Ca

Figure 2B: Evolution of the amounts of Mg

Figure 2: Evolution of the amounts of Calcium and magnesium in response to the contact of bean seeds with water

b. *Alkali cations*

The potassium contents (Figure 3A and Table 1) behave as follows: 0.0095g / l in the water used for cooking the seeds (E1), 1.255g / l after 30 minutes of soaking (E2), 1.294g / l after 60 minutes of soaking (E3), 2.358g / l after 60 minutes of soaking and 30 minutes of cooking (E4), 2.519g / l after 60 minutes of soaking and 60 minutes of cooking (E5), and 2.68g / l after 60 minutes of soaking and 90 minutes of cooking (E6). Concerning sodium (Figure 3B and Table 1), its contents change as follows: 0.0154g / l in the water used for cooking the seeds (E1), 0.008g / l after 30 minutes of soaking (E2), 0.019 after 60 minutes of soaking (E3), 0.034g / l after 60 minutes of soaking and 30 minutes of cooking (E4), 0.0596g / l after 60 minutes of soaking and 60 minutes of cooking (E5), and 0.07487g / l after 60 minutes of soaking and 90 minutes of cooking (E6). The intervention of temperature contributes to greatly increase the potassium and sodium contents in solutions even if the sodium concentrations remain low. Unlike potassium, the increase in sodium content occurs in conjunction with the duration of cooking. On the other hand, for potassium, the sudden increase is felt from the start of cooking; thereafter and until the end of the process, it increases rather slightly.

Figure 3A: Evolution of the amounts of K

Figure 3B: Evolution of the amounts of Na

Figure 3: Evolution of the amounts of potassium and sodium in response to the contact of bean seeds with water

c. *Ammonium*

Ammonium is the most concentrated cation. Its contents (Figure 4 and Table 1) change as follows: 0.009g / l in the water used for cooking the seeds (E1), 0.31g / l after 30 minutes of soaking (E2), 0.32g / l after 60 minutes of soaking (E3), 4,851g / l after 60 minutes of soaking and 30 minutes of cooking (E4), 5.183g / l after 60 minutes of soaking and 60 minutes of cooking (E5), and 5.41g / l after 60 minutes of soaking and 90 minutes of cooking (E6). We can then note that for this element,

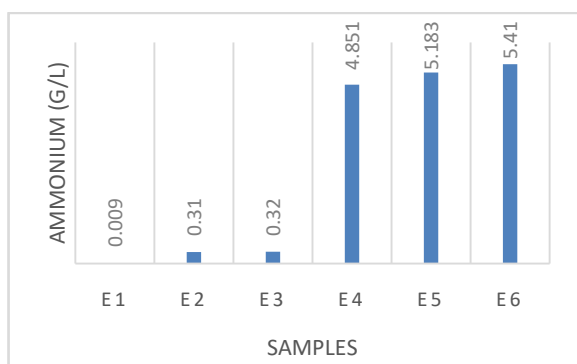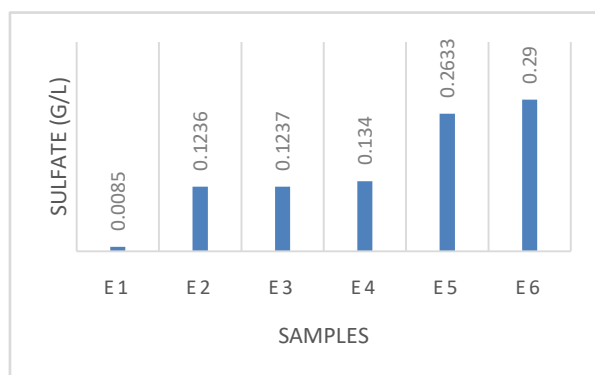the intervention of the temperature causes a strong increase in its concentration in the solutions.

Figure 4: Evolution of the amounts of NH_4^+ in response to the contact of bean seeds with water

d. *Anions*

Among the anions, the decreasing order of concentration of the elements in the different solutions is as follows: S>>>HCO3>>P>Cl.

The sulfate contents (Figure 5A and Table 1) change as follows: 0.0085g / l in the water used for cooking the seeds (E1), 0.1236g / l after 30 minutes of soaking (E2), 0.1237g / l after 60 minutes of soaking (E3), 0.134g / l after 60 minutes of soaking and 30 minutes of cooking (E4), 0.2633g / l after 60 minutes of soaking and 60 minutes of cooking (E5), and 0.29g / l

after 60 minutes of soaking and 90 minutes of cooking (E6). Concerning bicarbonate (Figure 5B and Table 1), its contents change as follows: 0.0013g / l in the water used for cooking the seeds (E1), 0.0012g / l after 30 minutes of soaking (E2), 0.0011 after 60 minutes of soaking (E3), 0.0026g / l after 60 minutes of soaking and 30 minutes of cooking (E4), 0.0182g / l after 60 minutes of soaking and 60 minutes of cooking (E5), and 0.095g / l after 60 minutes of soaking and 90 minutes of cooking (E6). These two most concentrated anions are also influenced by temperature. This physical magnitude allows them respectively to reach their respective highest content at the end of cooking. However, in the particular case of sulfates, its content increases suddenly and then remains relatively constant in the solutions from the start of soaking until the end of the thirtieth minute of cooking. At the end of the 60th minute of cooking, this content doubles before gradually increasing until the end of cooking. Regarding bicarbonates, their contents remain very low until the end of the thirtieth minute of cooking before being multiplied by 6 at the end of the sixteenth hour of cooking; at the end of the 90th hour of cooking, there is a more than sudden increase in these quantities, or they are multiplied by about 8.
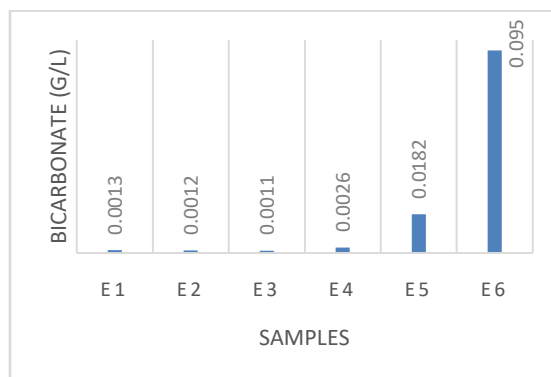

Figure 5A: Evolution of the amounts of SO_4^{2-}

Figure 5B: Evolution of the amounts of HCO_3^-

Figure 5: Evolution of the amounts of sulfates and bicarbonates in response to the contact of bean seeds with water

Regarding the levels of phosphates (figure 6A and Table 1), they are 0.00146g / l in the water used for cooking the seeds (E1), 0.001826g / l after 30 minutes of soaking (E2), 0.00246g / l after 60 minutes of soaking (E3), 0.0298g / l after 60 minutes of soaking and 30 minutes of cooking (E4), 0.0319g / l after 60 minutes of soaking and 60 minutes of cooking (E5), and 0.0333g / l after 60 minutes of soaking and 90 minutes of cooking (E6). For the chloride contents (Figure 6B and Table 1), we have 0.0016g / l in the water used for cooking the seeds (E1), 0.0034g / l after 30 minutes of soaking (E2), 0.0098 after 60 minutes of soaking (E3), 0.00476g / l after 60 minutes of soaking and 30 minutes of cooking (E4), 0.0171g / l after 60 minutes of soaking and 60

minutes of cooking (E5), and 0.029g / l after 60 minutes soaking and 90 minutes of cooking (E6). Despite the low levels of these two anions, they respond favorably to seed contact with water, and especially with the involvement of temperature. In the particular case of phosphates, its contents first increase very slightly until the sixtieth minute of soaking. From the start of cooking, this content is multiplied by 10 at the end of the thirtieth minute before continuing to increase gradually until the end of cooking. For chlorides, despite an unexplained drop at the end of the thirtieth minute of cooking, the tendency is upward, with the end of cooking as the time of reaching their maximum concentration.
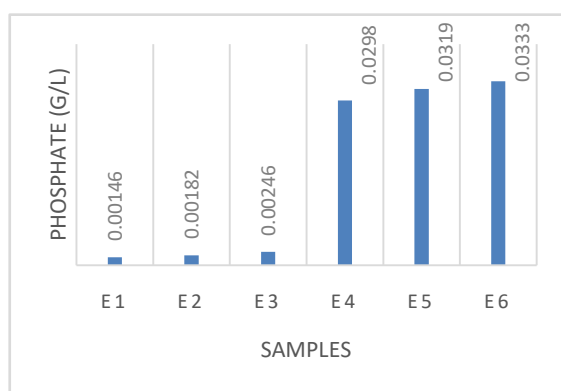
Figure 6A: Evolution of the amounts of HPO_4^{2-}
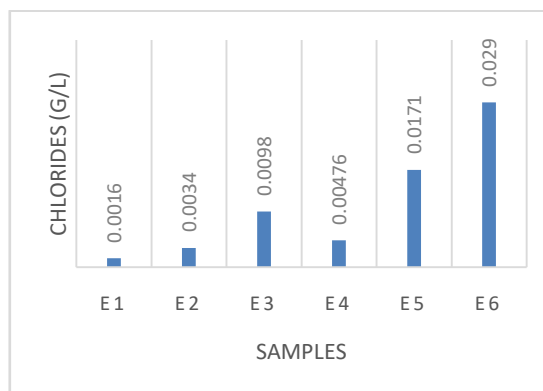

Figure 6B: Evolution of the amounts of chlorides

Figure 6: Evolution of the amounts of phosphates and chlorides in response to the contact of bean seeds with water

e. *EC et pH*

According to Figure 7A and Table 1, the values of electrical conductivity remain low. However, they increase gradually from the end of the thirtieth minute of soaking until the end of the cooking where the value is maximum. In detail, we have in turn 0.029 in the water used for cooking the seeds (E1), 0.071 after 30 minutes of soaking (E2), 0.169 after 60 minutes of soaking (E3), 0.303 after 60 minutes of soaking and 30 minutes of cooking (E4), 0.532 after 60 minutes of soaking and 60 minutes of cooking (E5), and 0.668 after 60 minutes of treping and 90 minutes of cooking (E6).

As for the pH, its value increases by about one unit at the end of the thirtieth minute of soaking (from 5.1 to 6.02). From this point on, there is a slight but constant increase until the end of cooking. We then have respectively 6.02 in E2, 6.1 in E3, 6.3 in E4, 6.41 in E5, and 6.45 in E6 (Figure 7B and Table 1).
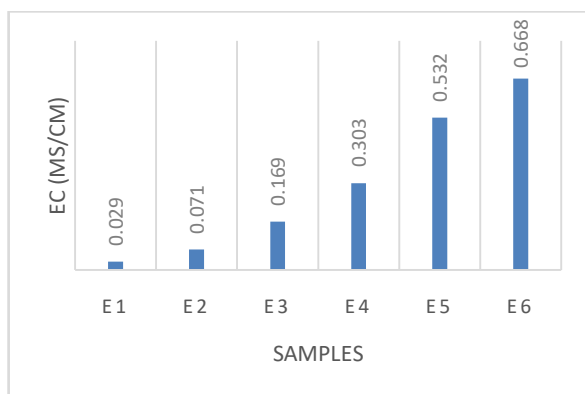
Figure 7A: Evolution of EC values
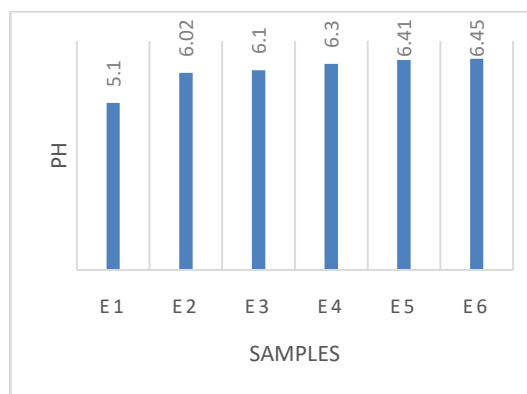
Figure 7B: Evolution of the pH values

Figure 7: Evolution of the EC and pH in response to the contact of bean seeds with water

From the above analysis, it appears that in the different solutions, ammonium followed by potassium are the two most concentrated main elements. They are followed from afar by magnesium, calcium, and sulfates, then very far by bicarbonates, sodium, phosphates and chlorides respectively (figure 8).
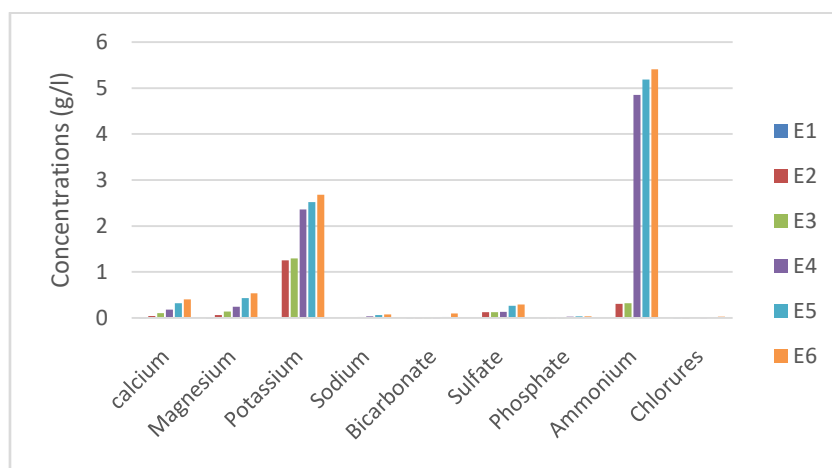
Figure 8: Global distribution of ions in solutions from the contact of bean seeds with water

c) *Correlation studies*

The correlation is positive and perfect linear between magnesium and calcium; the cloud seems to regroup in three sets (the two red points for the first set, the three blue points for the second set, and the yellow point almost halfway for the third set); the correlation coefficient here is 1 (Figures 9 and 63). That between calcium and potassium is just as positive with nonlinear positive monotonicity; the correlation coefficient is 0.8299 (Figures 10 and 63).Dots seem to constitute three groups: the three red dots for the first group, the middle yellow dot for the second group, and the two blue dots for the third group.
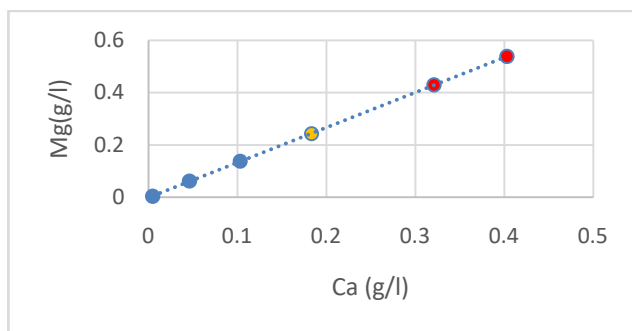
Figure 9: Ca^{2+} and Mg^{2+}correlation
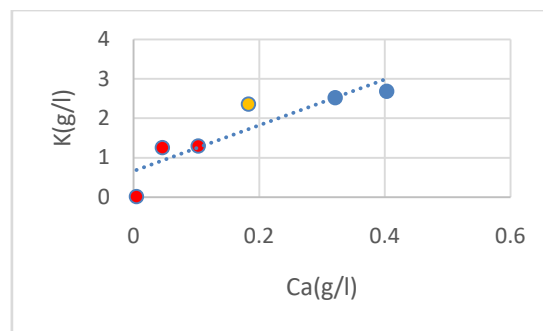
Figure 10: Ca^{2+} and K^{+} correlation

The correlation between sodium and calcium is positive with 0.9813 as correlation coefficient. The major trend is linear. However, we note a distribution of the points in three groups: the two yellow points for the first group, the almost median red point for the second group, the three blue points for the third group (Figures 11 and 63). The bond between bicarbonate and calcium appears to be positive, with a correlation coefficient of 0.7956. But, the grouping of points is very telling. Indeed, the first four points in blue, forming the first group, are arranged horizontally; red (second group) and yellow (third group) dots deviate from the first four respectively (Figures 12 and 63).

Table 1: Characterization of fluids during the process of soaking and beans cooking (mg/l)

	Masse totale (g)	pH	Ca2+	Mg2+	K+	Na+	CO_3^{2-}	SO_4^{2-}	HPO_4^{2-}	NH4+	Cl-	E.C. (mS/cm)
Eau simple (E1)	88.9	5.1	0.0045	0.0034	0.0095	0.0154	0.0013	0.0085	0.00146	0.009	0.0016	0.0290
Eau de trempage durant 30 minutes (E2)	91.3	6.45	0.046	0.062	1.255	0.008	0.0012	0.1236	0.00182	0.310	0.0034	0.071
Eau de trempage durant 60 minutes (E3)	94.2		0.103	0.138	1.294	0.019	0.0011	0.1237	0.00246	0.320	0.0038	0.169
Eau de cuisson durant 30minutes apres 60 minutes de trempage (E4)	98.3	6.46-6.47	0.183	0.244	2.358	0.034	0.0026	0.134	0.0298	4.851	0.00476	0.303
Eau de cuisson durant 60minutes apres 60 minutes de trempage (E5)	105	6.30	0.321	0.429	2.519	0.0596	0.0182	0.2633	0.0319	5.183	0.0171	0.532
Eau de cuisson durant 90minutes apres 60 minutes de trempage (E6)	109.6	6.31	0.403	0.538	2.63	0.07487	0.095	0.29	0.0333	5.41	0.029	0.668
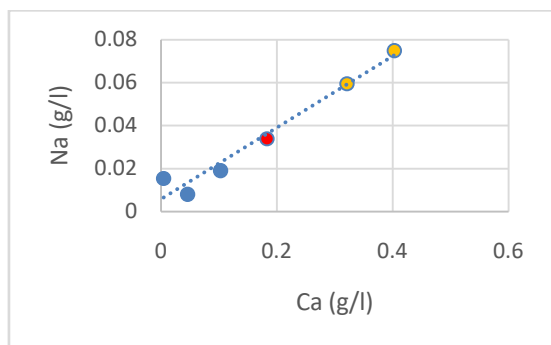
Figure 11: Ca^{2+} and Na$^+$ correlation
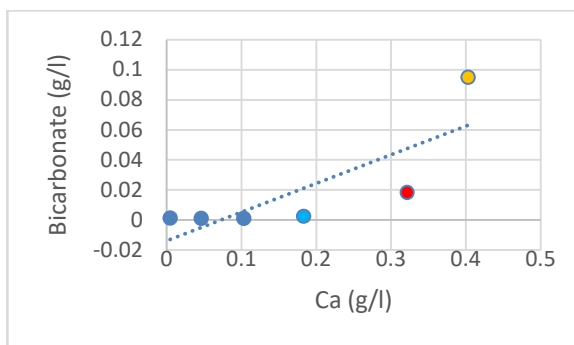
Figure 12: HCO$_3^{2-}$ and Ca^{2+} correlation

Figure 13 shows a positive nonlinear monotonic correlation between sulfate and calcium, with Pearson's coefficient 0.9537 (Figure 63). But in detail, we note the grouping of points in three sets: the yellow point for the first set, the three blue median points for the second set, and the two red points for the third set. Regarding Figure 14, it reveals equally a monotonic positive

nonlinear correlation between phosphate and calcium, withPearson'sindex 0.9051 (Figure 63). The clustering of points is just as notable here. Thus, we have the first group represented by the three blue dots, the second group represented by the red dot, and the third group represented by the two upper yellow dots.
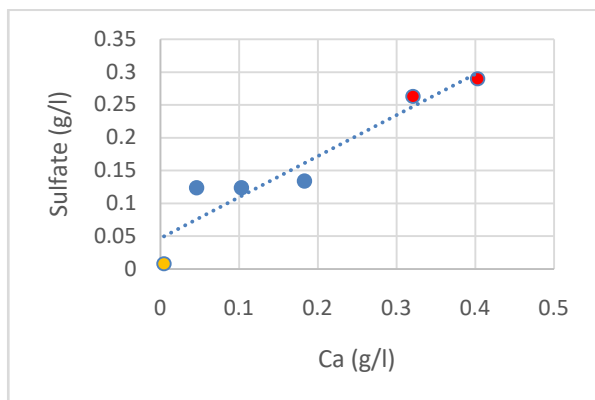
Figure 13: SO$_4^{2-}$ and Ca^{2+} correlation
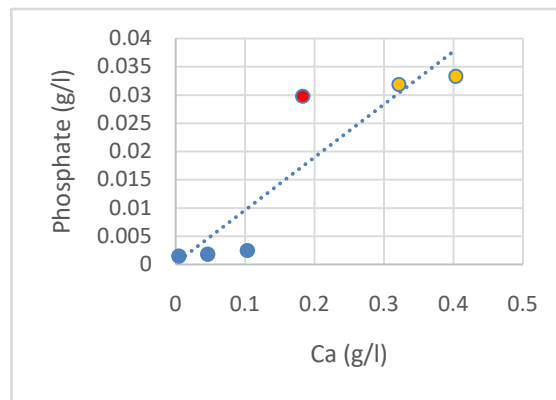
Figure 14: HPO$_4^{2-}$ and Ca^{2+} correlation

For Figure 15, it reveals an equally monotonic positive nonlinear correlation between ammonium and calcium, with Pearson's coefficient 0.9061 (Figure 63). The regrouping of the points here brings out a first group (the three blue points), a second group (the yellow point), and a third group (the two red points). Figure 16 for its one shows a globally monotonic

positive nonlinear binding between chlorides and calcium, with 0.923 as correlation coefficient (Figure 63). The distribution of points around the middle line shows a grouping into five groups: the two blue points (group 1), the red point (group 2), the yellow point (group 3), the green point (group 4), and the purple point (group 5).
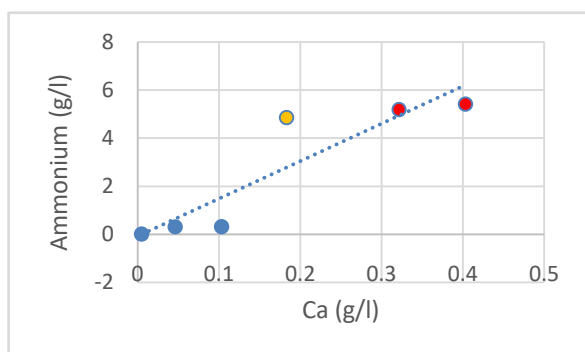

Figure 15: NH$_4^+$ and Ca^{2+}correlation

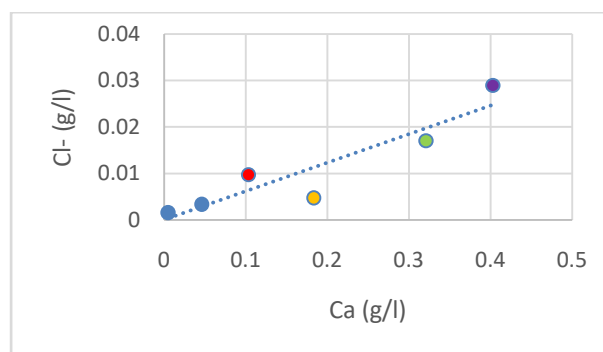*Figure 16:* Cl$^-$ and Ca^{2+} correlation

The correlation is almost linearly positive between electrical conductivity (EC) and calcium; the cloud seems to be grouped into three sets (the two blue points for the first set, the median red point for the second set, and the three yellow points for the third set); the correlation coefficient is 0.9994 (Figures 17 and 63). That between calcium and pH is non-linear monotonic positive, with the correlation coefficient 0.9081 (Figures 18 and 63); the points, located very high, seem to constitute three groups (the three blue points for the first group, the median red point for the second group, and the two yellow points for the third group). The steepest slope along the trendline is delimited between the first two blue points (from left to right); the rest of the points, almost perfectly aligned, generate a slight slope according to the trendline.
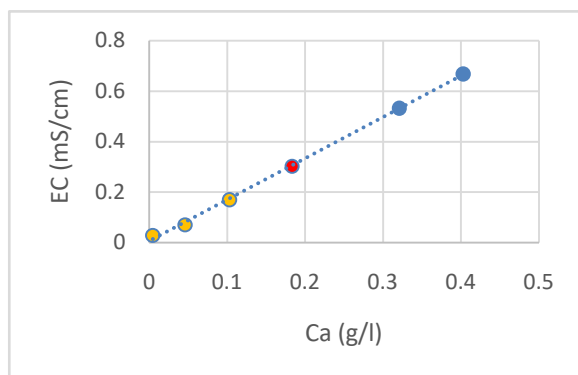
Figure 17: EC and Ca^{2+} correlation
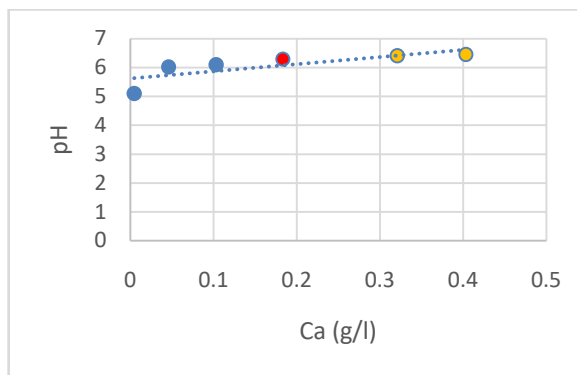
Figure 18: pH and Ca^{2+} correlation

Figure 19 shows a globally monotonic positive non-linear bond between potassium and magnesium, with the correlation coefficient 0.8942 (Figure 63). The distribution of points around the middle line shows a grouping into four groups: the two brown points (group 1), the red point (group 2), the two blue points (group 3), and the yellow point (group 4). The correlation between sodium and magnesium is positive with the correlation coefficient 0.16601. The major trend is linear. However, we note a distribution of the points in three groups: the two blue points for the first group, the almost median yellow point for the second group, the three red points for the third group (figure 20 and 63).
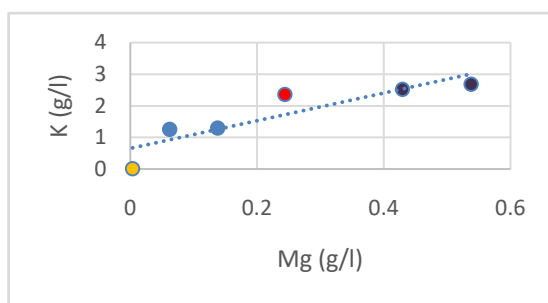

Figure 19: K$^+$ and Mg^{2+} correlation

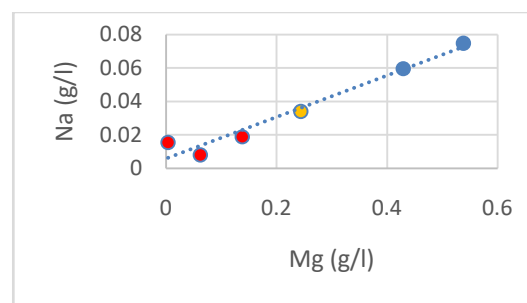*Figure 20:* Na$^+$ and Mg^{2+} correlation

The bond between bicarbonate and magnesium seems positive, with correlation coefficient 0.802. But, the grouping of points is very telling. Indeed, the first four points in blue, forming the first group, are arranged horizontally; the red (second group) and yellow (third group) dots respectively deviate from the first four (figures 21 and 63). The correlation between sulfate and magnesium is monotonic positive nonlinear, with the correlation coefficient 0.9515. We note a distribution of the points in three groups: the two yellow points for the first group, the three blue points for the second group, and the red point for the third group (figures 22 and 63).
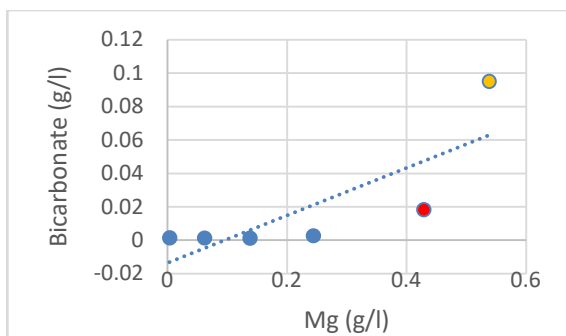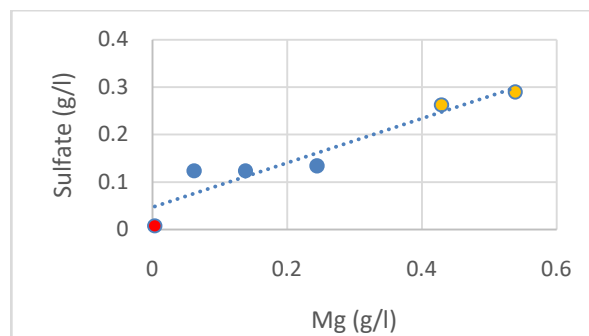
52

Figure 21: HCO$_3^-$ and Mg^{2+} correlation

Figure 22: SO$_4^{2-}$ and Mg^{2+} correlation

Figures 23 and 24 show a positive nonlinear monotonic correlation between phosphate and magnesium and between ammonium and magnesium, respectively. The correlation coefficient is 0.9044 in the first case and 0.9055 in the second case (Figure 63). The regrouping of the points here brings out a first group (the three blue points), a second group (the yellow point), and a third group (the two red points).
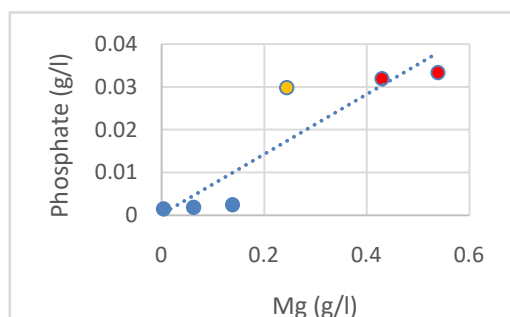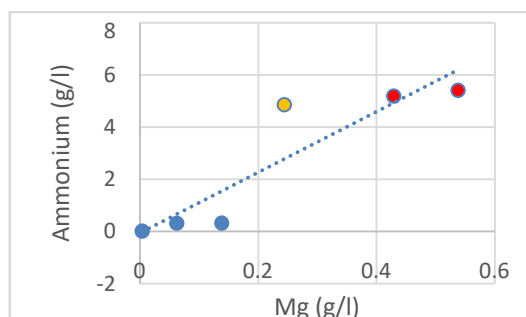

Figure 23: HPO$_4^{2-}$ and Mg^{2+}correlation

Figure 24: NH$_4^+$ and Mg^{2+} correlation

The correlation is globally positive nonlinear monotonic between chlorides and magnesium (Figure 25); their correlation coefficient is 0.9228 (Figure 63). The distribution of points around the middle line shows a grouping into five sets: the two blue points (group 1), the red point (group 2), the yellow point (group 3), the green point (group 4), the brown point (group 5). The

correlation is quite positive linear between electrical conductivity (EC) and magnesium; the cloud seems to be grouped into three sets (the three blue points for the first set, the median red point for the second set, and the two brown points for the third set); the correlation coefficient here is 0.9989 (Figures 26 and 63).
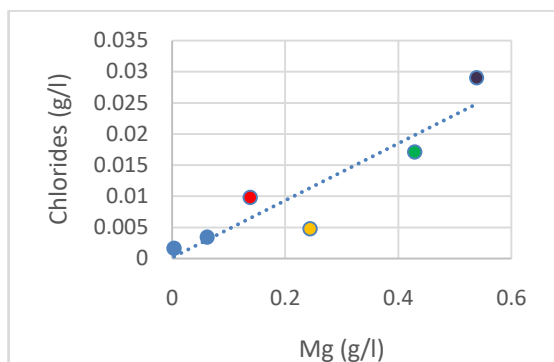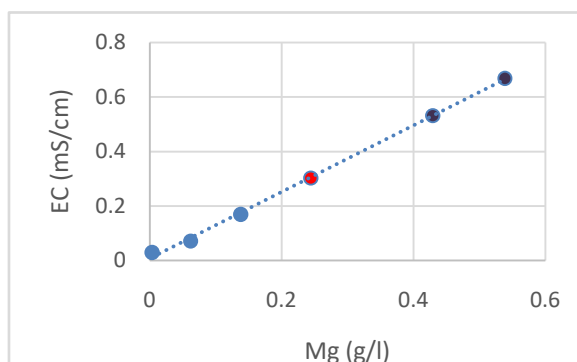

Figure 25: Cl$^-$ and Mg^{2+} correlation

Figure 26: EC and Mg^{2+} correlation

The bond between magnesium and pH is monotonic positive nonlinear, with coefficient of correlation 0.9236 (figures 27 and 63); the points, located very high, seem to constitute three groups (the three red points for the first group, the median yellow

point for the second group, and the two blue points for the third group). The steepest slope along the trendline is delimited between the first two red dots (from left to right); the rest of the points, almost perfectly aligned, generate a slight slope according to the trendline.

Regarding the correlation between sodium and potassium, it seems positive with regard to the trend curve (Figure 28), with the correlation coefficient 0.8031 (Figure 63). The scatter plot here reveals four groups:

the blue point for the first group, the two red points for the second group, the yellow point for the third group, and the two purple points for the fourth group.
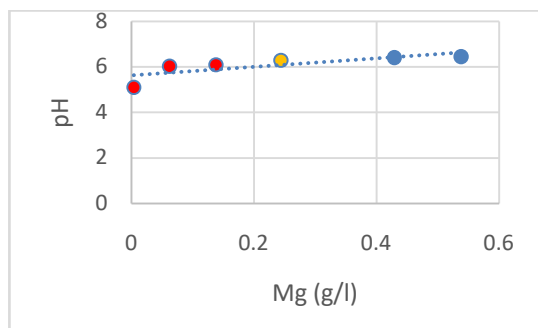

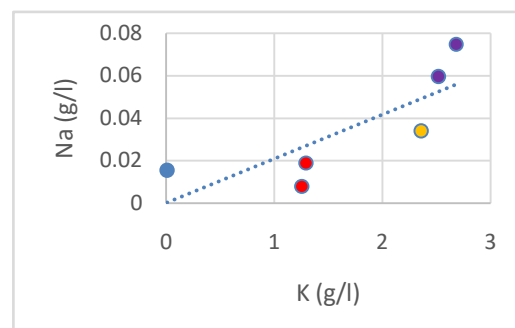Figure 27: pH and Mg^{2+} correlation

Figure 28: Na^+ and K^+ correlation

According to the trend curve in Figure 29, the correlation is positive between bicarbonate and potassium, with the correlation coefficient 0.6175 (Figure 63). But, the distribution of points is ambiguous, suggesting four groups: the red point for group 1, the two blue points for group 2, the two yellow points for group three, and the purple point for group 4. Also, we see that the points of group 1 and group 2 are completely aligned horizontally. From the analysis of

Figure 30, there is also a positive correlation between sulfate and potassium, with Pearson's coefficient 0.8577 (Figure 63). As before, the distribution of the points suggests four groups: the red point for the first group, the two blue points for the second group, the yellow point for the third group, and the two purple points for the fourth group. However, the points of the first and second group are well aligned along the trendline.
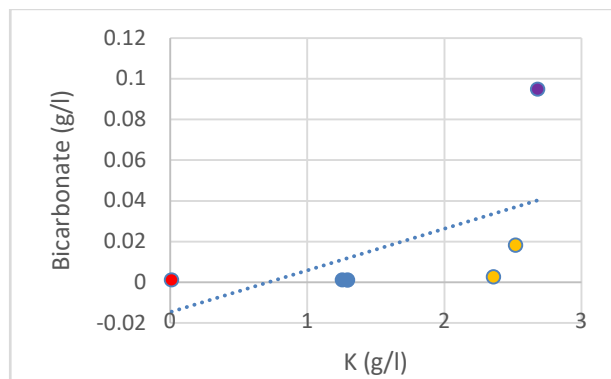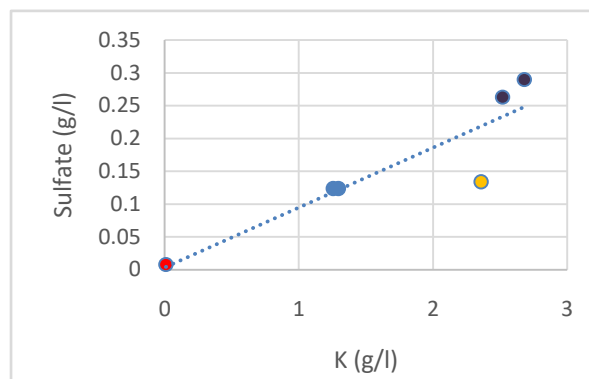

Figure 29: HCO_3^- and K^+ correlation

Figure 30: SO_4^{2-} and K^+ correlation

Figures 31 and 32 respectively highlight the positive correlation that exists between phosphate and potassium on the one hand, and between ammonium and potassium on the other. The correlation coefficients
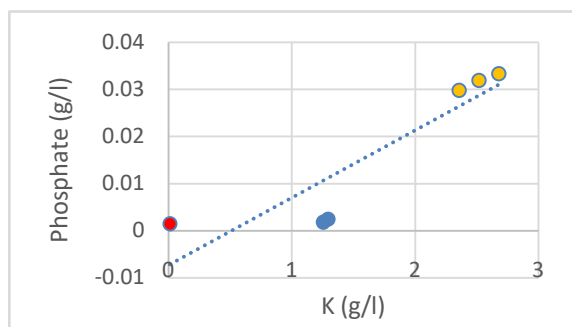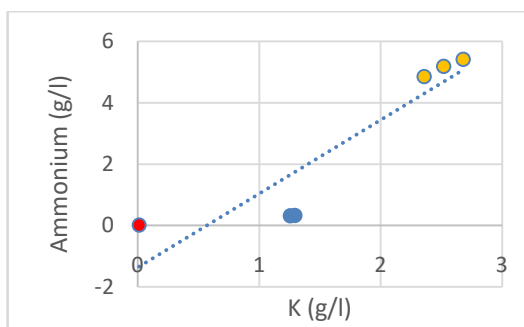
are 0.8995 and 0.9101 respectively (Figure 63). In both cases, the cloud generated brings out three groups: the red point for the first group, the two blue points for the second group, the three yellow for the third group.

Figure 31: HPO_4^{2-} and K^+ correlation

Figure 32: NH_4^+ and K^+ correlation

The correlation between chlorides and potassium is positive with regard to the trend curve (Figure 33); the correlation coefficient is 0.7109 (Figure 63). But, we note a strong dispersion between the points of the cloud, bringing out five groups in total: the red point for group 1, the two blue points for group 2, the yellow point for group 3, the green point for group four,

and the purple point for group 5. Concerning figure 34, it shows for its part a positive correlation between electrical conductivity (EC) and potassium, with the correlation coefficient 0.8797 (Figure 63). The dispersion of the dots brings out four groups: the red point for group 1, the two blue dots for group 2, the yellow point for group 3, and the two purple dots for group 4.
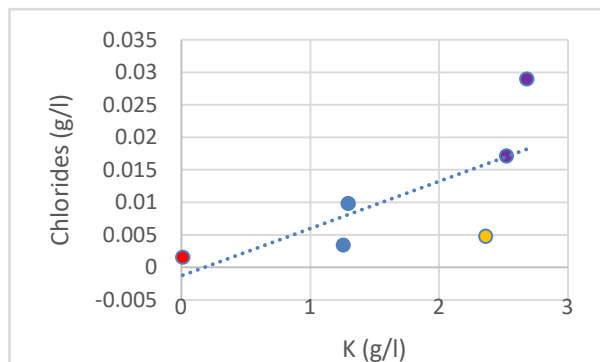

Figure 33: Cl⁻and K⁺ correlation

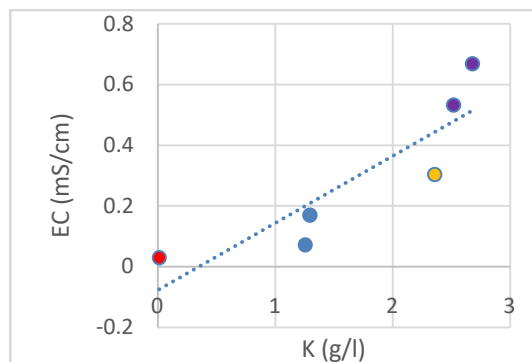*Figure 34:* EC and K⁺ correlation

The correlation is positive between pH and potassium (Figure 35), with Pearson's coefficient 0.9511 (Figure 63). The cloud of points, located very high, is organized into three groups: the red point for group 1, the two blue points for group 2, and the three yellow points for group 3. Overall, despite the dispersion points, they are all very close to the trendline. The correlation is also positive between sodium and

bicarbonate by referring to the trend curve (Figure 36); their correlation coefficient is 0.1405 (Figure 63). The cloud inducted individualizes four groups: the three blue points for the first group, the red point for the second group, the yellow point for the third group, and the purple point for the fourth group. But, the points of the first and second group line up horizontally along the abscissa axis.
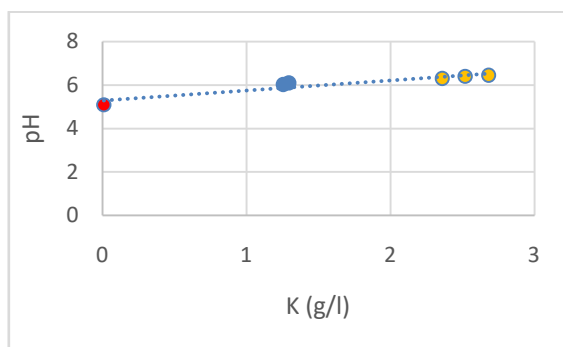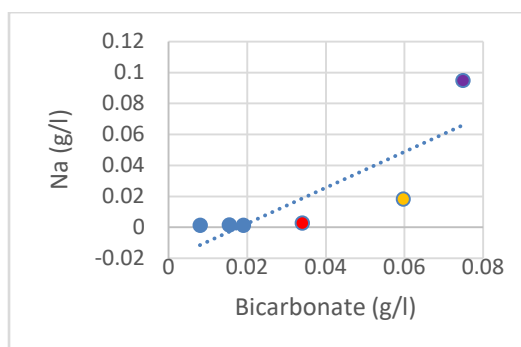

Figure 35: pH and K⁺ correlation

Figure 36: HCO₃⁻ and Na⁺ correlation

Figure 37 shows a positive correlation between sulfate and sodium, with the correlation coefficient 0.1503 (Figure 63). The distribution of points individualizes three groups: the red point for the first, the three blue points for the second, the two yellow points for the third. Figure 38 for its part also shows a positive correlation between phosphate and sodium with regard to the trend curve. The correlation coefficient is 0.1515 (Figure 63). The points of the cloud are individualized into three groups: the three blue points for the first, the red point for the second, and the two yellow points for the third.
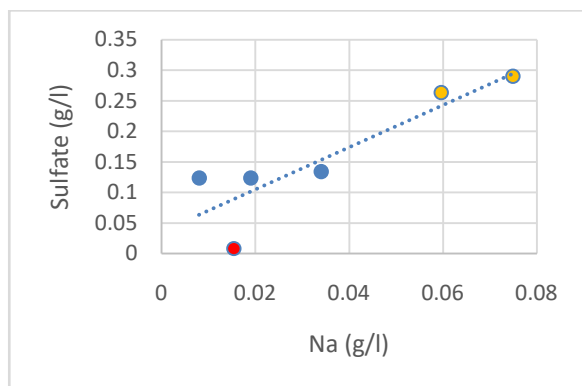
Figure 37: SO$_4^{2-}$ and Na$^+$ correlation

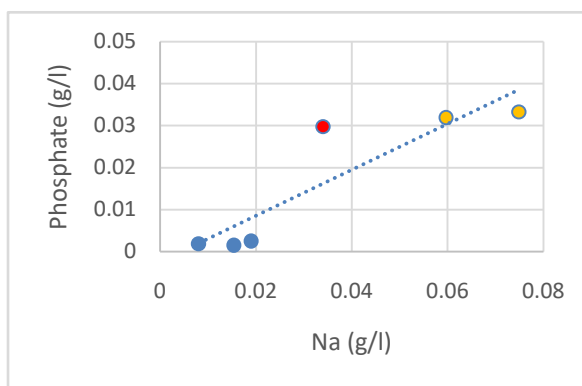*Figure 38:* HPO$_4^{2-}$ and Na$^+$ correlation

The trend line in Figure 39 shows a positive correlation between chlorides and sodium. The correlation coefficient is 0.1549 (Figure 63). The dispersion of the points of the cloud individualizes four groups: the three blue points for the first, the red point for the second, the yellow point for the third, and the purple point for the fourth. Regarding figure 40, the distribution of points highlights a positive correlation between electrical conductivity (EC) and sodium, with the Pearson's index of 0.1672 (Figure 63). The distribution of the points of the cloud reveals three groups: the three blue points for the first, the red point for the second, and the two yellow points for the third. The vast majority of points are almost carried by the trendline.
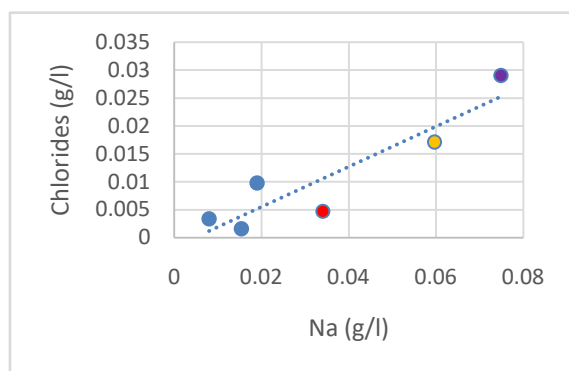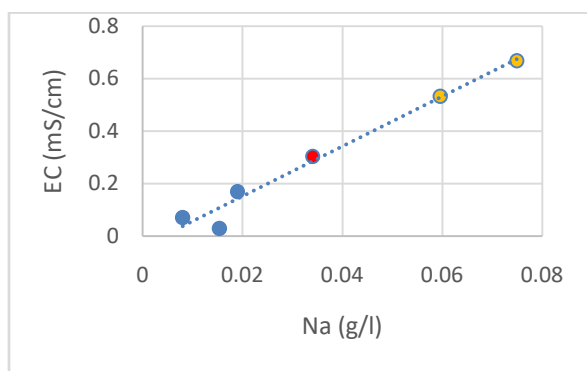

Figure 39: Cl- and Na$^+$ correlation

Figure 40: EC and Na$^+$ correlation

The correlation is positive between pH and sodium (Figure 41), with 0.1312 as the correlation coefficient (Figure 63). Located high, the scatter plot for the most part clusters very close to the trendline. Also, this cloud individualizes three groups: the three blue points for the first, the red for the second, and the two yellow points for the third. The trend curve in Figure 42 shows a positive correlation between sulfate and bicarbonate, with the correlation coefficient 0.7332 (Figure 63). The distribution of points reveals four groups: the red point for the first, the two blue points for the second, the yellow point for the third, the purple point for the fourth. We note in detail that the fourth group is very eccentric with respect to the other three groups.
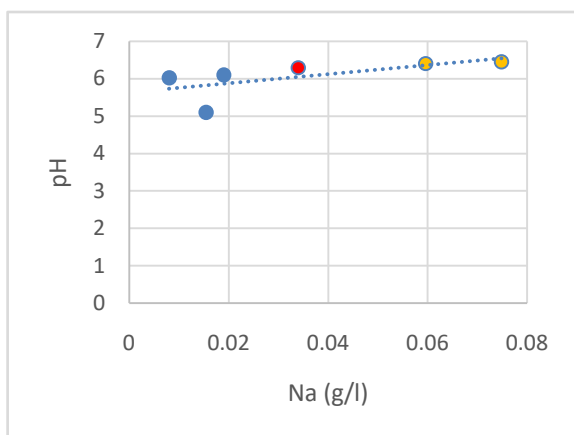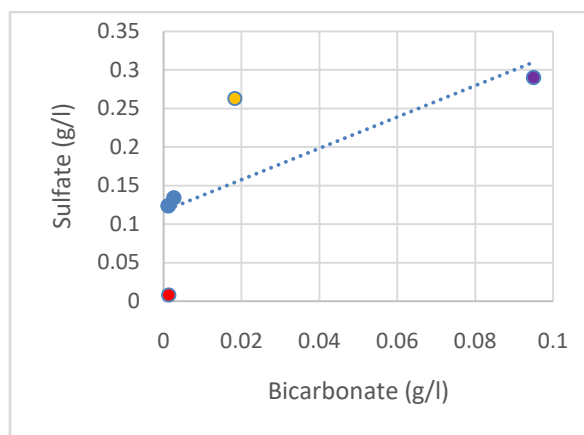
Figure 41: pH and Na+ correlation

Figure 42: SO$_4^{2-}$ and HCO$_3^{2-}$ correlation

In Figures 43 and 44, there is a positive non-linear monotonic correlation between phosphate and sulfate on the one hand and between ammonium and bicarbonate on the other hand. The correlation coefficients are respectively 0.5972 and 0.5949 (Figure 63). The distribution of points shows four groups in the first case and three groups in the second case. In the first case we have: the two blue points for the first group, the red point for the second group, the two yellow points for the third group, and the purple point for the fourth group. In the second case, we have: the three blue points for the first group, the two yellow points for the second group, and the red point for the third group. In both cases, if the first groups tend to approach, the last group is completely eccentric.
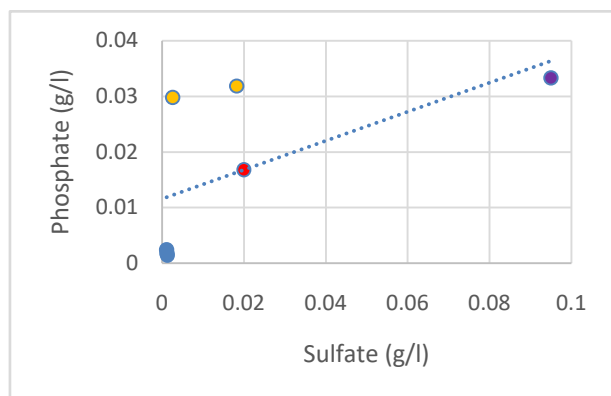
Figure 43: HPO$_4^{2-}$ and HCO$_3^-$ correlation
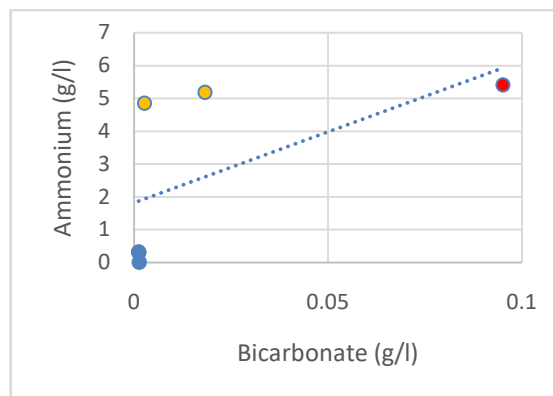
Figure 44: NH$_4^+$ and HCO$_3^-$ correlation

Figures 45 and 46 show a monotonic positive non-linear correlation between chlorides and bicarbonate on the one hand and between electrical conductivity (EC) and bicarbonate on the other. The correlation coefficients are respectively 0.9138 and 0.8088 (Figure 63). The distribution of points highlights three groups in both cases: the three blue points for the first group, the two yellow points for the second group, and the red point for the third group. In both cases, if the first two groups tend to come closer, the last group is completely eccentric. Also, the points of the first group and one of the points of the second group are almost vertically arranged along the y-axis.
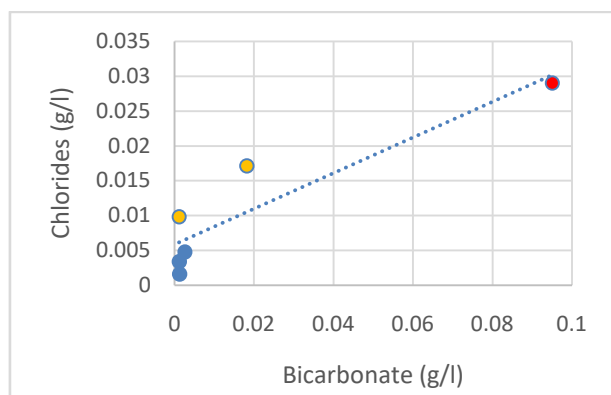
Figure 45: Cl- and HCO$_3^-$ correlation

Figure 46: EC and HCO$_3^-$ correlation

The correlation is positive nonlinear monotonous between the pH and the bicarbonate (Figure 47), with the correlation coefficient 0.4522 (Figure 63). The point cloud is high. Most of these points are concentrated towards the left end of the trendline. This cloud individualizes three groups: the four blue points for the first, the red point for the second group, and the yellow point for the third group. The correlation between phosphate and sulfate (Figure 48) on the one
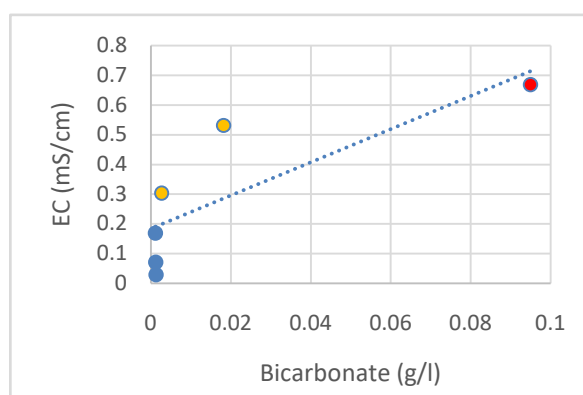
hand and between ammonium and sulfate (Figure 49) on the other hand is monotonic positive nonlinear, with correlation coefficient 0.8003 and 0.8060 respectively (Figure 63). The point cloud in both cases is organized into four groups: the brown point for the first, the two blue points for the second, the yellow point for the third, the two red points for the fourth. We note in detail that these groups are highly distant from each other.
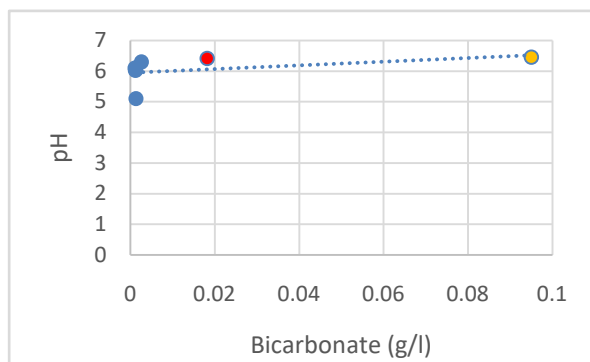
Figure 47: pH and HCO$_3^-$ correlation

Figure 48: HPO$_4^{2-}$ and SO$_4^{2-}$ correlation

Regarding the correlation between chlorides and sulfates (Figure 50), the correlation between electrical conductivity (EC) and sulfate (Figure 51), and the correlation between pH and sulfate (Figure 52) respectively, the trend curve shows that it is globally linear positive, with the respective correlation coefficient 0.8987, 0.3662, 0.8696 (Figure 63). The point cloud of

the pH-sulfate correlation has the particularity of being very high. Overall, this cloud makes it possible to visualize three groups of points, relatively distant from each other: the red point for the first group, the three blue points for the second group, and the two yellow points for the third group.

Fugure 49: NH$_4^+$ and SO$_4^{2-}$ correlation
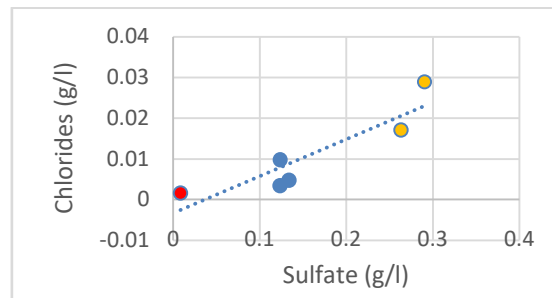
Figure 50: Cl$^-$ and SO$_4^{2-}$ correlation
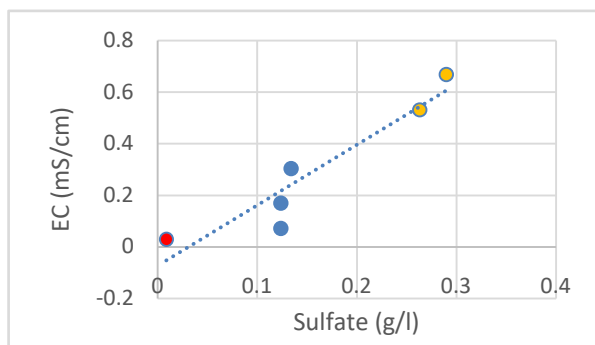
Figure 51: EC and SO_4^{2-} correlation
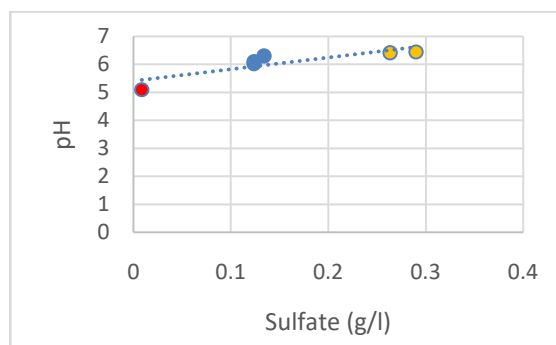
Figure 52: pH and SO_4^{2-} correlation

The trendline of the correlation between ammonium and phosphate (Figure 53), pH and ammonium (Figure 54), and pH and phosphate (Figure 55) shows a positive relationship. The correlation coefficient is 0.7964 in the first case, 0.7395 in the second case, and 0.7275 in the third case (Figure 63).

The point cloud initiated by the correlation pH-NH_4^+ and pH-$HPO_4$2- is positioned higher (Figures 54 and 55). But, in all three cases, this cloud individualizes two main groups, distant from each other: the three blue dots for the first group and the three red dots for the second group.
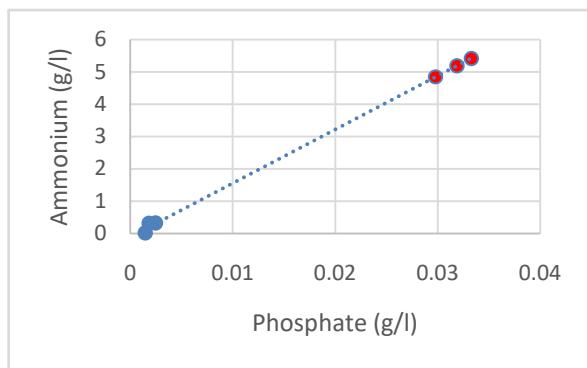
Figure 53: NH_4^+ and HPO_4^{2-} correlation
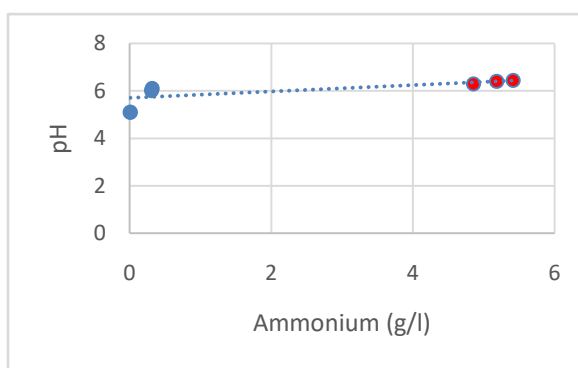
Figure 54: pH and NH_4^+ correlation
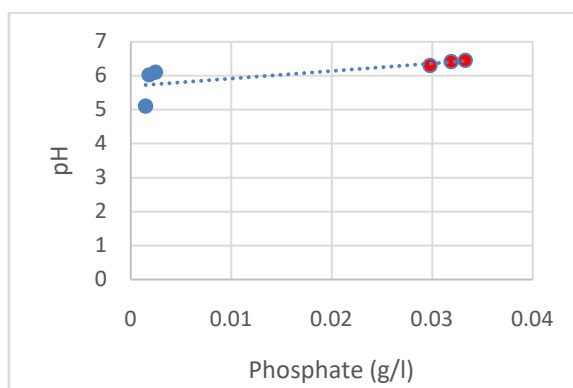
Figure 55: pH and HPO_4^{2-} correlation

Regarding the correlation between electrical conductivity (EC) on the one hand (Figure 56) and the correlation between electrical conductivity and phosphate on the other hand (Figure 57), the trend line shows a positive correlation. The respective correlation coefficients are 0.9065 and 0.9064 (Figure 63). The cloud of points individualizes three groups: the three blue points for the first group, the red point for the

second group, and the two yellow points for the third group.

Figure 56: EC and NH$_4^+$ correlation
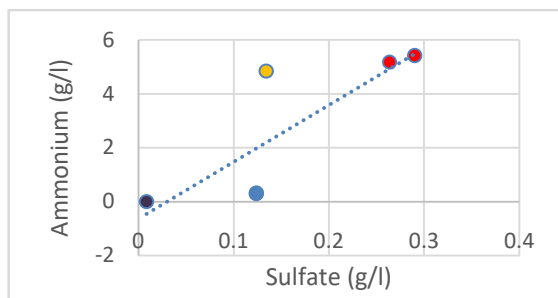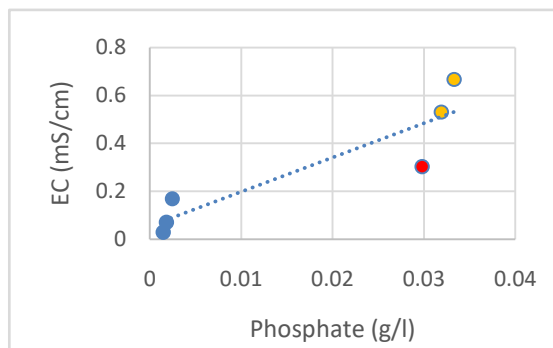

Figure 57: EC and HPO$_4^{2-}$ correlation

In the context of the correlation between chlorides and ammonium (Figure 58) on the one hand and between phosphates and chlorides (Figure 59) on the other hand, the trend curve shows a positive relationship. The correlation coefficients are 0.6826 and

0.6823 respectively (Figure 63). The scatter plot shows four groups: the three blue points for the first group, the red point for the second group, the purple point for the third group, and the yellow point for the fourth group.
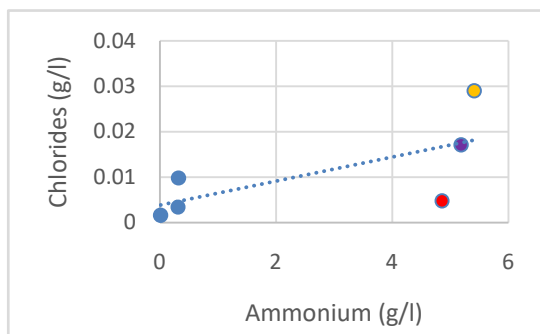
Figure 58: Cl$^-$ and NH$_4^+$ correlation
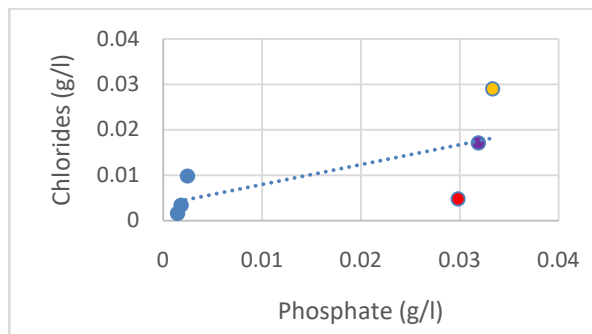
Figure 59: HPO$_4^{2-}$ and Cl$^-$correlation

The trend curve for the correlation between pH and chlorides (Figure 60) on the one hand and between pH and electrical conductivity (EC) on the other hand (Figure 61) shows a positive relationship in both cases, with for respective correlation coefficient 0.6456 and 0.7576 (Figure 63). The distribution of points here brings out three groups for each of these cases. Regarding the correlation between pH and chlorides, the groups are:

the four blue points for the first group, the red point for the second group, and the yellow point for the third group. Regarding the second case, the groups are: the three blue dots for the first group, the red dot for the second group, and the two yellow dots for the third group. In both cases, the third group is distant from the first two groups.
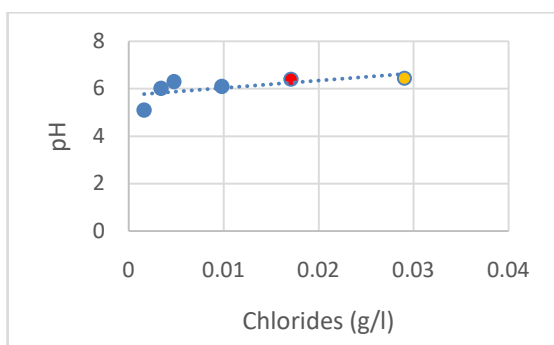
Figure 60: pH and Cl$^-$ correlation
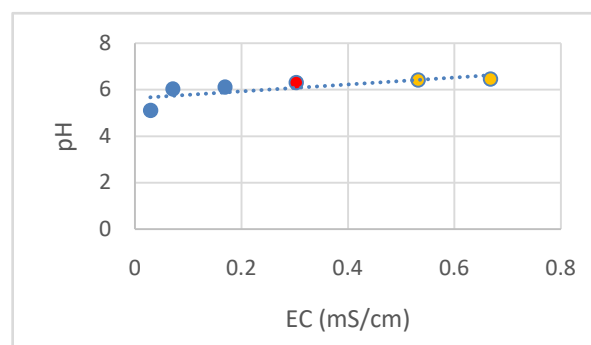
Figure 61: pH and EC correlation

Figure 62 highlights a generally linear positive correlation along the trendline. The correlation coefficient is 0.9235 (Figure 63). The cloud of points makes it possible to visualize three groups: the four blue

points for the first group, the yellow point for the second group, and the red point for the third group. In detail, these three groups are significantly distant from each other.
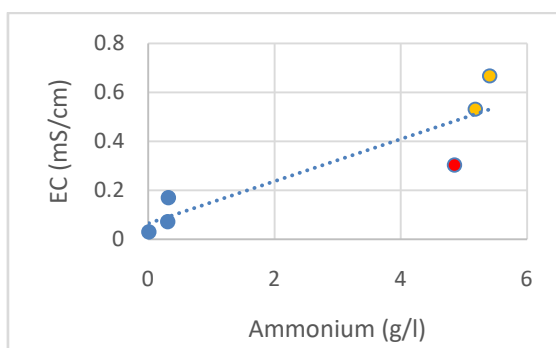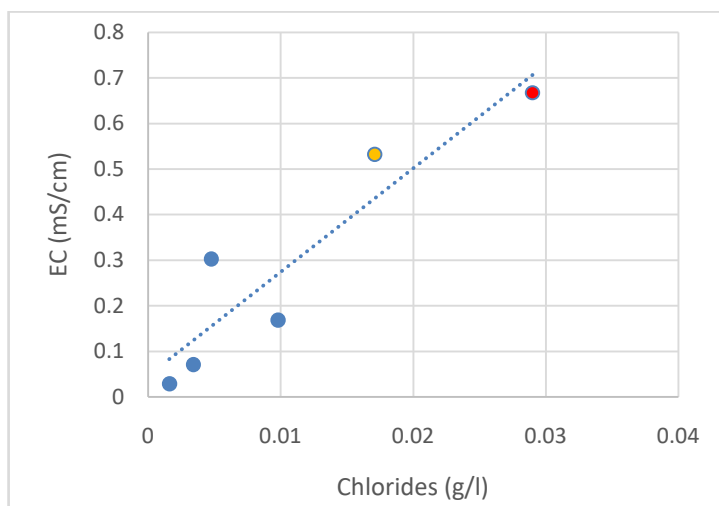
Figure 62: EC and Cl⁻ correlation

	Ca²⁺	Mg²⁺	K⁺	Na⁺	HCO₃⁻	NH₄⁺	SO₄²⁻	HPO₄²⁻	Cl⁻	EC	pH
Ca²⁺	1										
Mg²⁺	1	1									
K⁺	0.8299	0.8942	1								
Na⁺	0.9813	0.16601	0.8031	1							
HCO₃⁻	0.7956	0.802	0.6175	0.1405	1						
NH₄⁺	0.9061	0.9055	0.9101	0.1509	0.5949	1					
SO₄²⁻	0.9537	0.9515	0.8577	0.1503	0.7332	0.8061	1				
HPO₄²⁻	0.9051	0.9044	0.8995	0.1515	0.5972	07964	0.8003	1			
Cl⁻	0.923	0.9228	0.7109	0.1549	0.9138	0.6826	0.8987	0.6823	1		
EC	0.9994	0.9989	0.8797	0.1672	0.8088	0.9065	0.3662	0.9064	0.9235	1	
pH	0.9081	0.9236	0.9511	0.1312	0.4522	0.7395	0.8696	0.7275	0.6456	0.7576	1

Figure 63: Matrix of correlation

d) *Mass variations of the beans during soaking and cooking processes*

During soaking and cooking the beans, one can denote the mass loss at the different stages by bean seeds (Figure 64 and Table 2). However, the mass loss is lower during the soaking of the beans compared to the situation observed during the cooking process. In detail, from 100g at the beginning (mt), the mass reaches 97.6g after 30 minutes of soaking (mht30cr), 94.7g after 60 minutes of soaking (mht60), 90.6g after 60 minutes of soaking and 30 minutes of cooking (mht60cu30), 83.9g after 60 minutes of soaking and 60 minutes of cooking (mht60cu60), and 79.3g after 60 minutes of soaking and 90 minutes of cooking (mht60cu90). Then, compared to the initial situation (mt), the loss is as follow: 2.4g, 5.3g, 9.4, 16.1g, 20.7g respectively in mht30cr, mht60cr, mht60cu30, mht60cu60, mht60cu90 stages (Figure 64).

Table 2: Mass variations of the beans during soaking and cooking processes

	mt	mht30cr	mht60cr	mht60cu30	mht60cu60	mht60cu90
M(g)	100	97.6	94.7	90.6	83.9	79.3
Perte de masse (g)	0	2.4	5.3	9.4	16.1	20.7
Pourcentage de matière perdue (%)	0	2.4	5.3	9.4	16.1	20.7
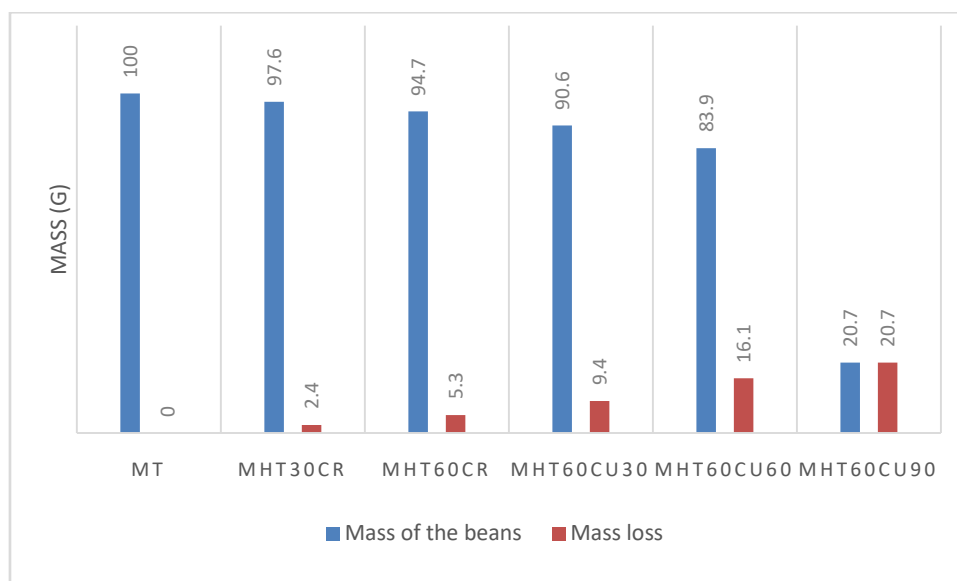
IV. DISCUSSION

When the seeds are soaked, the amounts of the various target ions in the scope of this study increase significantly. During boiling, the stage after the soaking phase, this increase is greater. Overall, this increase is due to the hydrolysis of reserves contained in the cotyledons according to [31] and [32], the main seed storage organs as proved by [33]. The products resulting from this hydrolysis then pass through the teguments by diffusion to end up in the soaking or cooking solutions. Rachidi (2012) explains this integument crossing by relying on the permeable or semi-permeable character of biological membranes. This postulate corroborates the observations made by [35]. The sudden increase in the quantities of ions in solution during cooking is justified by the fact that the temperature, high or low, greatly influences the lysis of compounds (Davis, 1983). The addition of the amounts of Ca^{2+}, Mg^{2+}, K^+, Na^+, SO_4^{2-}, HPO_3^{2-}, Cl^-, NH_4^+, Cl^-, and HCO_3^- in the soaking or cooking solutions is in accordance with the composition of bean seeds as highlighted by [24] have shown this. In addition, [35] completes these observations by specifying the amounts of sulfur in bean seeds. NH_4^+ and HCO_3^- come from the hydrolysis of organic compounds present in the cotyledons, in particular proteins for the first ion, and carbohydrates and lipids for the second ion. This is in agreement with the results of [36]. Likewise, the increase in pH and electrical conductivity (EC) is noted. The increase in pH is the consequence of the increase in the amounts of exchangeable basic cations in soaking or cooking solutions. This observation is commonly made in soil physiology by pedologists like [37], [35], etc. Regarding electrical conductivity (EC), this is a quantity that is related to the presence of electrolytes in solution. Its behavior is consistent with the increase in ion quantities in the solutions followed here. However, according to [38], it is weak. This is the consequence of the low sodium contents in the solutions. The main ions contained in the solutions are NH_4^+ and K^+ respectively, followed by Mg^{2+}, Ca^{2+}, SO_4^{2-} for the most abundant. This is in accordance with the order of decreasing concentration of bean seeds in these different elements. However, one can also relate the enrichment of solutions resulting from cooking bean seeds in Ca^{2+}, Mg^{2+}, K^+, and SO_4^{2-} to the fact that these elements are highly influenced by temperature. In this sense, [39] and [40] shows through his two series of crystallization of minerals in a magmatic environment that the Ferromagnesians (forsterite type olivines) crystallize parallel to the calcium feldspars (anorthites) at high temperature. Lower, that is, at a lower temperature, crystallize potassium and sodium silicates, followed by other minerals. Moreover, it has been observed that during volcanic eruptions, many gases including sulfur

dioxide are released [41]. This ease of sulfur to express in the presence of heat is consistent with the increase in sulfates in bean seed cooking solutions.

Further on, all the correlations are positive between the parameters followed in this present study. This is in agreement with the joint increase of these different parameters. One would therefore be tempted to think that the different parameters influence each other in solutions when bean seeds are soaked or boiled. However, a detailed observation shows that the point clouds organize themselves into groups, and that the points of several of these groups are arranged either horizontally as is the case in the correlation between sodium and bicarbonate, potassium and bicarbonate, bicarbonate and magnesium, and between bicarbonate and calcium, either vertically, as is the case in the correlation between electrical conductivity and bicarbonate, chlorides and bicarbonates, phosphates and sulfates, ammonium and bicarbonate, sulfate and bicarbonate, pH and bicarbonate, electrical conductivity and sulfate, and between electrical conductivity and ammonium. This demonstrates independence in the behavior of the parameters concerned according to the work of [42]. This is the reason why in a magmatic environment, some minerals will form first before others depending on the environmental conditions. Also, the points of the clouds organize themselves in groups which are sometimes very distant. This is the consequence of the presence of another underlying parameter which controls the behavior of the elements involved in the correlation. This is in agreement with the observations made by [42]. On a completely different level, we can see that in the organization of point clouds, many points are completely off-center, imposing a final trend that does not correspond to reality. This is the case in the correlation between pH and bicarbonate, electrical conductivity and bicarbonate, sulfate and bicarbonate, phosphate and sulfate, ammonium and bicarbonate, sulfate and bicarbonate, bicarbonate and potassium, bicarbonate and magnesium, and between bicarbonate and calcium. This corroborates the notable independence in the behavior of certain parameters taken in pairs according to [42]. In the same vein, the trendline of the correlations between some of these elements taken into account are linear positive as is the case for the correlation between calcium and magnesium, or even non-linear monotonic positive as it is the case for the correlation between pH and chlorides, pH and electrical conductivity, pH and phosphate, pH and ammonium, pH and bicarbonate, chlorides and bicarbonate, electrical conductivity and bicarbonate, ammonium and bicarbonate, phosphate and sulfate, and between magnesium and pH. [42] explains this fact by specifying that in this case, the value of one of the elements concerned in the correlation can, depending on the environmental conditions, strongly or weakly influence that of the other. This is in accordance with the temperature variation brought into play in the present study through the simple soaking and cooking of bean seeds channel. The correlations involving sodium have the lowest coefficients. This reflects a low degree of enrichment of sodium in solutions. This can be justified by the starting composition of bean seeds, which have low concentrations of this element, in particular about 2 mg per 100 g of bean seeds according to [24]. Such a cause and effect phenomenon has also been observed in the magmatic environment, where the composition of the final rock is closely related to that of the starting magma as shown by [40]. Still in the analysis of correlations, we see that between magnesium and calcium, the correlation is positive and perfect linear, with correlation coefficient 1. By drawing a parallel with the magmatic environment once again, we will notice that in [39]'s crystallization series, forsterite-type Ferromagnesians (Magnesian olivine) and anorthite-type calcium feldspars (calcium plagioclase) are the first minerals to form in the respective series, in particular the discontinuous series (black minerals) and continuous series (white minerals).

In the various solutions resulting from the contact between bean seeds and water, and especially in those whose production has undergone the intervention of temperature, the three main nutrients are, and in order of importance, nitrogen, potassium, and magnesium. According to [43], this are two of the three major macroelements (N and K), and one of the minor macroelements (Mg). After these three elements, we have the other minor macroelements (Ca and S) analyzed within the framework of the present study, and the trace elements here represented by the chlorides. Concerning the third major macroelement, in particular phosphorus, its contents are rather low. These contents in solutions, compared with those of calcium and magnesium, do not agree with the contents in seeds as showed by [24]; in fact, the phosphorus contents of bean seeds are at least twice the calcium and magnesium contents respectively. The phosphorus contents in the solutions could therefore have been at least comparable to those of calcium and magnesium. However, [44] clarifies the mystery by declaring at the end of his work that phosphorus is rather an element sensitive to the composition of the environment. In this sense, this author shows that in the presence of calcium among other things, the phosphate reacts with it to precipitate in the form of calcium phosphate as showed by [45], thus becoming not very concentrated in the solution. This is in agreement with the observations of [11].Also, by referring to the correlations established between phosphorus and calcium, between phosphorus and magnesium, between phosphorus and potassium, and between phosphorus and sodium, we see in the cloud of points the formation of groups of points the

arrangement of which is reminiscent of staircases, that is to say sequentially linear, thus revealing not only the influence that these elements can have on each other taken two by two, but also revealing the impact of temperature on their behavior according to [42]. Further on, we will establish such a theory by referring to the magmatic medium or in the same rocks, where we will find mineral associations highlighting the presence of magnesian (forsterite), calcium (anorthite), phosphate (apatite), sodium (albite) as shown by [41]. Apart from the nutrients observed here, notably the major macroelements, minor macroelements, and trace elements, the bean end-of-cooking solution has a very high water content as showed by [46]. In addition, [13] showed that the bean end-of-cooking solution, at rest, settles, depositing organic matter. It is therefore a complete fertilizer. [13] has showed this quality by testing this solution as a substrate for heterotrophic beings, whose food needs are summed up in water, mineral salts, and organic matter according to [47]. The parallelism drawn by [46] between this solution and human urine supports the observations made by [12].

During the processes of soaking and cooking the beans, one can denote the differential mass loss at the different stages by bean seeds.This situation is due to the more or less extended duration of the contact between the bean seeds and the water. In that vein, [48] demonstrated the lysis capacity of water when it gets in contact with matters. According to [49], the products from the bean lysis traversed the seeds membrane and reach the solutions drowning the beans. This is consistent with the increase of the concentrations of the different ions followed up in the case of the present study. However, the mass loss is lower during the soaking of the beans compared to the situation observed during the cooking process. After [50], the involvement of temperature often increases the intensity of chemical reactions. This is in accordance with the amount of mass loss at different stages. In that point of view, compared to the initial situation, the loss of matter is 2.4g after 30 minutes of soaking. After 60 minutes of soaking, the loss is a little more than the double (5.3g) of the amount previously observed. After 60 minutes of soaking and 30 minutes of cooking the beans, the lost is quite the double (9.4g) of the former amount. After 60 minutes of soaking and 60 minutes of cooking the beans, the loss is equally quite the double (16.1g) of that observed before. After 60 minutes of cooking and 90 minutes of cooking the beans, the loss is about 1.3 time (20.7g) that of the earlier situation. The reduction of the increasing in losing the matter can be due to the progressive reach of the saturation point of the solutions as demonstrated by [51].

V. CONCLUSION

Solutions obtained from beans soaking and beans cooking are gradually enriched in mineral salts, particularly major macro elements (N and K), minor macro elements (Ca, S, Mg), and oligoelements compared to the situation noticed in the water used for the cooking process. Concerning the third major macro element, notably the phosphorous, it is present in low amounts. The pH and the electric conductivity (EC) of the solutions increase with the duration of the soaking and cooking processes. The amounts and values start their weak increasing thirty minutes after the beginning of the soaking, and continue their shy increasing up to the end of the sixtieth minute of the soaking. With the beginning of the cooking process, the increasing become abrupt. The correlation between all the parameters followed up in the present study are globally positive. But some facts reveal the independence between some of the parameters taken into account here. Also, the study of the clouds of dots reveal the impact of the temperature as the major responsible of the behavior of some of those elements despite the positive correlations established. The Pearson index in the correlations including sodium are the lowest.

VI. RECOMMANDATION

Consumers would benefit from recycling the bean end-of-cooking water. This recycling can be done by reintroducing this water in the rest of the bean cooking processes, either as inputs in pig feed, or then as fertilizer. To keep the water at the end of cooking the beans, it is advisable to put it in a cool place if it is stored for gastronomic purposes, or directly in the ground if it is stored for agrarian purposes.The use of solutions from cooked beans as fertilizers must be directly followed by earthing up in other to avoid the loose of nitrogen and sulfur through gas emanation. It use does not require any dilution.

Competing Interests
Authors have declared that no competing interests exist.

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