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SIMULATION OF THE REGULARITY OF COMPRESSED EARTH BRICKS WITH THICK LIQUID FROM BANANA STEM USING EXPERIMENTAL DESIGN

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ABSTRACT

In the current context of accelerated climate change and increasing global population, the construction industry faces crucials challenges : reducing its environmental impact while meeting the growing demand for housing. Addressing these challenges, this study focuses on improving construction materials using natural stabilizers, such as a thick liquid extracted from banana tree trunks. The mechanical characteristics in the dry state presented by each type of compressed earth brick are then analyzed for each implementation process.

Understanding the behavior of compressed earth bricks requires specific comprehension of the elements constituting them. This work aims to determine, using the design of experiments method, a set of predictive models related to the proportions of the components of bricks formulated from thick liquid extracted from banana tree trunks. A factorial design was adopted to model the influence of three essential parameters related to the mixture's cohesion and strenght : soil ratios, thick liquid extracted from banana tree trunks, and processing duration. These data analysis methods enable the gathering, summarizing, and presentation of information to extract the most insights for future experiments. The design of experiments methodology assists researchers in structuring their approach innovatively, validating hypotheses, gaining a better understanding of the studied phenomena, and problem-solving. To conduct planned experimental research, formulations and mathematical models are developed to predict both the workability and strength of the bricks, highlighting the relationships and interactions between different factors using Minitab software.

Keywords : Earth brick, stabilization, thick liquid from banana tree trunk, formulation, modeling, experimental design, Minitab.

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1. INTRODUCTION

In many developping countries, housing is a fundamental element for people to live decently. In the case of Madagascar, construction materials have been developed over several years but the housing sector has still worsened, especially with the use of clay bricks [1]. The majority of the Malagasy population still uses wood as a fuel. However, the environment is deteriorating over time due to human action. Human activities particularly deforestation, significantly impact biodiversity and contribute to the depletion of natural resources. The high carbon footprint resulting from the use of these fuels raises questions about environmental protection.

It is widely accepted within the scientific community that since the beginning of the Industrial Revolution, accelerated climate change has been induced by human activities. The main cause of greenhouse gas (GHG) emissions into the atmosphere is energy production and consumption, especially the combustion of fossil fuels, which releases carbon dioxyde. Results obtained from the study done by (Siddick et al., 2021) confirmed that production and consumption had a substantial impact on global carbon dioxyde emissions, which are a major concern regarding climate change [2].

The emissions of carbon dioxyde (CO_2) are largely attributable to human activities such as the combustion of fossil fuels (such as coal, oil, and natural gas), industrial processes, and deforestation. These CO_2 emissions, along with other greenhouse gases, have a significant impact on global warming by trapping heat in the Earth’s atmosphere, thus contributing to climate changes observed on a global scale. The United Nations also forecasted that millions of people would die not due to war and conflict but due to increasing pollution and global warming (Martin, 2016) [3].

To provide a solid foundation for higher levels of carbon dioxyde emission reductions, this study represents a major advancement in the field of eco-friendly construction in Madagascar. By utilizing local resources such as the banana plant to reinforce compressed earth bricks, we aim to diminish the environmental impact of construction industry. These organic binders derived from natural plants would therefore serve as promising stabilizers for modern compressed earth brick constructions and are within reach of majority of the Malagasy population.

By combining traditional construction knowledge with technological advancements, this study introduces a sustainable and environmentally respectful method for creating construction materials. The approach adopted, involving the analysis and use of experimental plans via Minitab software,signifies a crucial methodological advancement. By linking various variables to brick characteristics, this method allows for optimizing material production while reducing environmental impact. The application of this methodology, coupled with the use of local natural resources, represents a significant leap for sustainable construction in Madagascar.

The originality of this article proposes an innovative and comprehensive approach that combines traditional constrution method with scientific advancements to create sustainable environmentally friendly solution accessible to local community.

2. MATERIALS

2 .1 Clay and thick liquid extracted from banana trees

Clay is an abundant raw material, omnipresent in all regions of the island of Madagascar. Clay is a malleable substance that is easy to extract locally without worrying of the cost and transportation from longer distances. Clay is one of the rarest substances which does not posses an intrinsic value. However, it could be used to transform in to numerous valuable objects [4]. Therefore, the studies conducted focus on utilizing local resources, specifically the clayey soil, the main component of the earth brick made by mixing it with the thick liquid extracted from banana trees, also known as raw earth bricks. Consequently, our objective is to develop low-cost, easily manufactured, environmentally friendly local construction materials. Therefore, it is crucial to determine whether the incorporation of these natural stabilizers with the clayey soil could enhance the mechanical strength of the materials produced. The verification of mechanical performance was carried out using xperimental planning.

2 .2 Compressed Earth Bricks

In our study, we produced compressed earth bricks using the thick liquid extracted from banana tree trunks as a base [5]. The various parameters in this study are soil content, thick liquid from the trunk, and processing time.

During the brick formulation process, the formulas and results are presented in Tables 1, 2, and 3:

- The first table addresses soil treatment with varying levels of thick liquid from the banana tree trunk (5%, 10%, 15%, and 20% by mass).
- The two additional tables (Tables 2 and 3) depict the formulation and results obtained during the soil treatment process.

The objective of these tests is to investigate the effects of additive incorporation on the physical properties to achieve favorable outcomes.

Subsequently, our focus shifts to modifying and optimizing the process of using thick liquid from banana tree trunks in brick production.

2.3 Chosen Design

We employed a two-level factorial design, taking into account each component of the compressed earth brick.

The processes undertaken are as follows:

- Mixing the soil with sand.
- Mixing the soil with 5% thick liquid from the trunk and 5% sand.
- Gradually adding thick liquid from the banana tree trunk at 10%, 15%, and 20%. The low and high levels of liquid quantity were set based on estimations derived from common practices.
- The treated soil is typically incorporated into the mixture.
- For the factor of processing time, we selected the high level as 6 weeks and the low level as one week to observe the mixture's evolution over time.

2.4 Factors

The factors targeted in this research encompass the percentages of key components required for crafting compressed earth bricks: water, sand, soil, thick liquid from the trunk, and processing time. All measurements are in mass percentage at the fresh state, with processing time measured in weeks.

2.5 Factor Levels

The selection of parameter ranges for the various factors was determined based on the compressed earth brick formulas presented in Table 4. A series of formulations were conducted.

2.6 Responses

To gauge the impact of the binder on the clayey soil, we examined the changes in the dry state compression strength of the specimens.

2.7 Choice of Experimental Design [5. 6]

The choice of an experimental design allows us to consider the three factors at two levels, resulting in a total of 2^3 = 8 experiments. Given that this number is acceptable for laboratory work, a full factorial design proves to be the most suitable for this study due to its enhanced precision.

We selected a complete 2^3 factorial design (three factors at two levels).

The matrix of effects for the chosen factorial design is presented in Figure 1.

2.8 Interactions

- Third-order interactions:

For the factorial design (Soil: So, Trunk: tr, Time: t), the interactions are as follows: So*tr, So*t, tr*t, So*tr*t.

We have 4 interactions, 3 factors, and 8 formulation trials, leading to a matrix with 8 rows and 7 columns (4 interactions + 3 factors) [7]

The effects matrix with interactions is presented in Figure 2.

3. METHODS

3.1 Minitab Software

Minitab is statistical software originally developed by the Department of Statistics at the University of Pennsylvania (USA). It is particularly well-suited for the statistical analysis of small, well-structured data tables, including descriptive statistics, analysis of variance, correlation and multiple regression methods, time series analysis, independence tests, non-parametric methods, principal component analysis, discriminant analysis, statistical quality control, experimental designs, and more.

The Windows graphical interface enhances usability and result presentation. The use of dialogue boxes via the menu bar spares users from needing to know syntax.

3.2 Creating an Experimental Design [7. 8]

Before inputting or analyzing measurement data in Minitab, we need to create an experimental design and save it in a worksheet. Depending on the experiment's requirements, there are various types of plans. Minitab simplifies plan selection by providing a list of all available plans.

Once we choose a plan and its specifications, Minitab automatically generates and saves it in the worksheet. The process is as follows:

- ✓ Opening:

To start a Minitab session in the Windows environment, simply "double-click" the blue Minitab icon (Figure 3).

- ✓ Familiarizing with Minitab's Configuration:

When opening Minitab for the first time, two main windows appear: Session and Worksheet. The Session window displays analysis results, while the Worksheet window is used for data entry (Figure 4). The Worksheet window resembles an Excel spreadsheet.

- ✓ Entering Data Series Name:

On the second row of the worksheet, enter the names of our data series. The first row is reserved by the software and contains references like C1, C2, C3, etc. for Minitab's use.

- ✓ Entering Data in Different Columns:

After labeling columns, input the corresponding data. Press Enter after each entry to move to the next cell (Figure 5).

- ✓ Clicking on the Stat Menu:

Once data is entered, click on the Stat menu at the top of the window. Choose the desired analysis by hovering the cursor over the Stat menu and making a selection.

3.2.1 Creating a Factorial Design [9]

After entering our data, click on the Stat menu - DOE (Design of Experiments) - Factorial Design - Create Factorial Design (Figure 6, 7).

A new window opens.

- Display Available Designs:

Click on "Display Available Designs. Minitab will show all possible plans along with the required number of trials in the dialogue box. Display Available Designs (Figure 8).

3.2.2 Analyzing a Factorial Design [9]

Click on the Stat menu - DOE (Design of Experiments) - Factorial Design - Analyze Factorial Design (Figure 9, 10).

A new window opens.

On the left, double-click on the variables we want to analyze. The variable will then appear in the Factors frame. Click OK in each dialogue box.
Display Available Designs:

- Display Minimum and Maximum Values (figure 11):

Click on Min/Max, Minitab displays the minimum and maximum values of the factors. Then click OK.

- Display Responses: On the left, double-click on the "dry compression strength" response. The variable will appear in the Responses frame. Click OK (Figure 12).

3.2.3 Factorial Plot (Figure 13, 14, 15)

To create a factorial plot, follow these steps:
After entering our data, click on the Stat menu - DOE (Design of Experiments) - Factorial Design - Factorial Plots [10].
The Factorial Plots window opens, and then click OK.

- Visualize the Model:

Click on "Visualize the Model." Minitab displays the response "dry compression strength" and all possible factors and interactions between factors.

3.2.4 Response Optimization (Figure 16, 17)

Click on the Stat menu - DOE (Design of Experiments) - Factorial Design - Response Optimization. The Response Optimization window opens, choose "Maximize" and then click OK [9], [10].

3.2.5 Surface Plot

The three figures (Figure 18, 19, 20) illustrate the creation and selection of a surface plot. Click on the Graph menu - 3D Surface Plot.
Choose the surface plot type and then click OK.
On the left, double-click on the studied factors. These factors will appear in the Z, Y, X variable frames. Click OK [11].

4. RESULTS

The operational parameters studied are trunk, processing time, and soil.

4.1 Factorial Regression:

Coded coefficients, model summary, analysis of variance, and the regression equation are obtained through a factorial regression executed using the statistical analysis software Minitab. According to this software, the results are represented in Tables 5, 6, 7:

- Coded Coefficients (Table 5)
- Model Summary (Table 6)
- Analysis of Variance (Table 7)

With p-value: Significant value of the models

- Regression Equation in Coded Units

Dry Compression Strength = 42.76 - 2.17 Soil + 6.86 Processing Time + 12.22 Soil*Thick Liquid from Trunk - 0.48 Soil*Processing Time + 3.13 Soil*Thick Liquid from Trunk*Processing Time

4.2 Normalized Effects Pareto Chart

The PARETO chart of normalized effects of the new Rc dry model for a risk of 0.1 is presented in Figure 24.

4.3 Factorial Plots for Dry Compression Strength

The factorial plot displays the essential effects of the studied factors on the dry material's compression strength. These effects are presented in Figure 25.

4.4 Interaction Diagrams for Rc dry

The interaction diagram allows us to measure the relationship between soil, trunk, and processing time. It is depicted in Figure 26.

4.5 Response Optimization: Dry Compression Strength

The graph shown in Figure 27 is the result of response optimization.

4.6 Surface Plot of Soil in Relation to Sugar and Maturation Time

The surface plot restricts the study domain for the studied factors, as shown in Figure 28.

5. DISCUSSION

5.1 Factorial Regression:

All effects that extend beyond the reference line are significant at the default level of 0.1 (Figure 24). This implies that columns exceeding the red dashed line, which represents the limit considered statistically significant, hold importance. Based on the PARETO chart, we interpret that the interaction A*B presents a high histogram, indicating that interactions A*B, in other words, Soil*Trunk, play a crucial role in the brick's compression strength concerning time "t". Furthermore, The time factor has a very significant effect, indicating that homogenization of the mixture occurs rapidly with time. This increases the density and compactness of the brick.

Physical Interpretation:

According to the obtained results (Table 7), coefficients are evaluated as follows:

- Processing Time "t"

The effect of processing time is significant with a positive coefficient of (0.13). As time increases, homogenization of the mixture occurs, leading to increased density and compactness of the brick.

- Soil (So) * Trunk (tr)

The positive value of the SoilTrunk coefficient (0.79) indicates that the quantity of added trunk in the soil positively influences the material's mechanical strength. Additionally, interactions of the three factors SoilTrunk*Processing Time have a significant effect on the material, as indicated by the positive coefficient value (0.30).

- Soil (So) * Processing Time (t)

Preceded by a positive sign (0.79), interactions between Soil (So) and Processing Time (t) factors positively impact the value of Rc dry resistance, leading to increased strength.

The linear correlation coefficient $R^2 = 0.83$, while the software predicted a value of 0.63. The adjusted value is 0.74 according to the software. We consider this adjusted value R2 = 0.74 (Table 6).

Finally, the p-value judges whether factors have a statistically significant influence on the response: if $p < 0.05$, then Soil factors ($p = 0.01$) have a statistically significant influence on the response since they have factors with $p < 0.05$.

5.2 Factorial Plots for Dry Compression Strength

Figure 25 illustrates how increasing processing time improves compression strength, showing an ascending line (with a steep positive slope) originating from 35 and reaching 50. This implies that the processing time factor exhibits significant variation in compression strength. On the other hand, the presence of soil in the model demonstrates less variation in strength, as indicated by the short study domain and a clearly negative slope.

5.3 Interaction Diagrams for Rc dry

For the interaction effect (Figure 26), SoilTrunk interactions positively influence the increase in Rc dry brick compression strength. Conversely, SoilProcessing Time interactions reduce the compression resistance of the brick.

5.4 Response Optimization: Dry Compression Strength

The goal is to analytically determine optimal values for operational parameters influencing the mechanical resistance process of the material. Optimization is illustrated in Figure 27. Red points represent optimal factor parameters, while blue points indicate the predicted response concerning resistances designed with these parameters.
From Figure 27, an optimal compression resistance can be achieved at 6 weeks of age, using red-colored values, i.e., a soil dosage of 75% and a trunk dosage of 10% for each brick constituent. These constituent dosages yield an optimal Rc dry resistance of 67.62 bar.

Physical Interpretation:

The adjusted value found, Rc dry = 67.62 bar, falls within the 95% confidence interval and the 95% prediction interval. This implies that this value is reliable for consumers.
The adjusted value Rc dry = 67.62 bar should be achieved with soil 75%, trunk 10%, and a processing time of 6 weeks.

5.5 Surface Plot of Soil in Relation to Trunk and Processing Time

We interpret the numerical synthesis of variables using a surface plot representation (Figure 28). In the shaded green study domains, we pay particular attention to the three factors (soil, trunk, and processing time). By tracing surface plot curves in green, we visualize the optimum. This signifies that the chosen domains for each variable correspond to the green surfaces. Within this domain, we can work effectively. This domain is constructed and bounded to meet consumer demand, delineating areas of interest. By choosing to work within the center of this zone, we achieve results that perfectly align with the study's objectives, namely, optimization.

Table 1 : Formulations used for soil and trunk treatment

Trial	Soil	Trunk	Sand
1	95	-	5
2	90	5	5
3	85	10	5
4	80	15	5
5	75	20	5

Table 2 : Results obtained for dry state compression strength of specimens « BCtr 5,10,15,20% »

Processing Time (Weeks)	**1**	**2**	**4**	**6**
BCPSa5tr5	23,2	25,6	27,9	30,1
BCPSa5tr10	37,5	41,2	47,9	49,6
BCPSa5tr15	31,6	33,2	40,4	44,6
BCPSa5tr20	29,4	31,5	36,2	37,4

Table 3 : Factor levels

Factors	**Levels**	
Soil	75	-1
	95	+1
Trunk	5	-1
	20	+1
Water	20	No levels
Sand	5	
Time of treatment	1	
	6	

Table 4 : ANOVA Table providing coefficients Ai, Aij, Aijk of the preliminary model

Terms	Effects	coefficient
Soil	-4,35	-2,17
Time of treatment	13,71	6,86
Soil*Trunk	24,45	12,22
Soil*time of treatment	-0,96	-0,48

Table 5 : Model summary

R-aquared	Adjusted R-aquared	Predected R-aquared
83,017%	74,51%	63,26%

Table 6 : Analysis of Variance

Source	P-value
Soil	0,01
Time of treatment	0,13
2 factor interactions	0,00
Soil*Trunk	0,00
Soil*time of treatment	0,79
3 factor interactions	0,30
Soil*Trunk*Time of treatment	0,30

$$\begin{pmatrix} -1 & -1 & -1 \\ +1 & -1 & -1 \\ -1 & +1 & -1 \\ +1 & +1 & -1 \\ -1 & -1 & +1 \\ +1 & -1 & +1 \\ -1 & +1 & +1 \\ +1 & +1 & +1 \end{pmatrix}$$

Figure 1: Effects Matrix

$$\begin{pmatrix} -1 & -1 & -1 & -1 & +1 & +1 & +1 \\ +1 & -1 & -1 & -1 & -1 & -1 & -1 \\ -1 & +1 & -1 & -1 & -1 & +1 & +1 \\ +1 & +1 & -1 & -1 & +1 & -1 & -1 \\ -1 & -1 & +1 & -1 & +1 & -1 & +1 \\ +1 & -1 & +1 & -1 & -1 & +1 & -1 \\ -1 & +1 & +1 & -1 & -1 & -1 & +1 \\ +1 & +1 & +1 & -1 & +1 & +1 & -1 \end{pmatrix}$$

Figure 2: Effects Matrix with Interactions

Figure 3: Minitab Logo

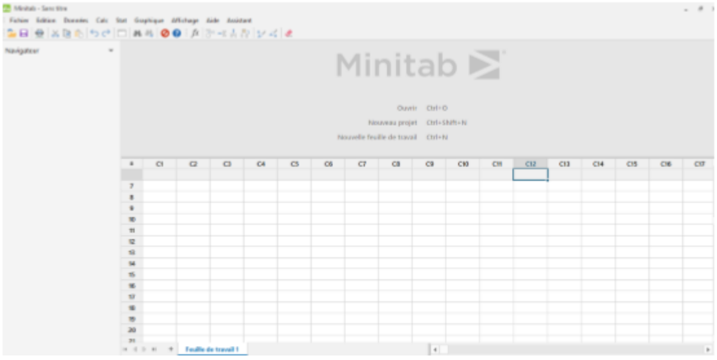
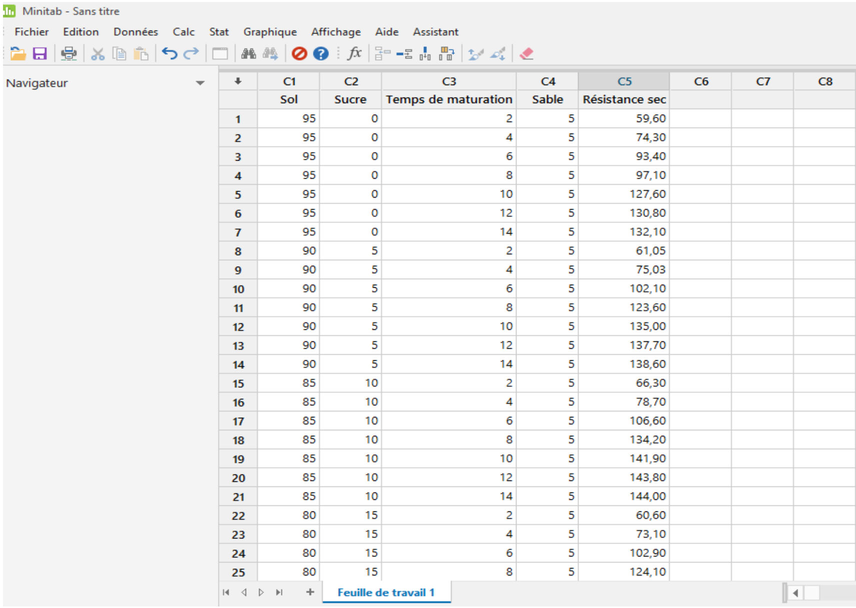
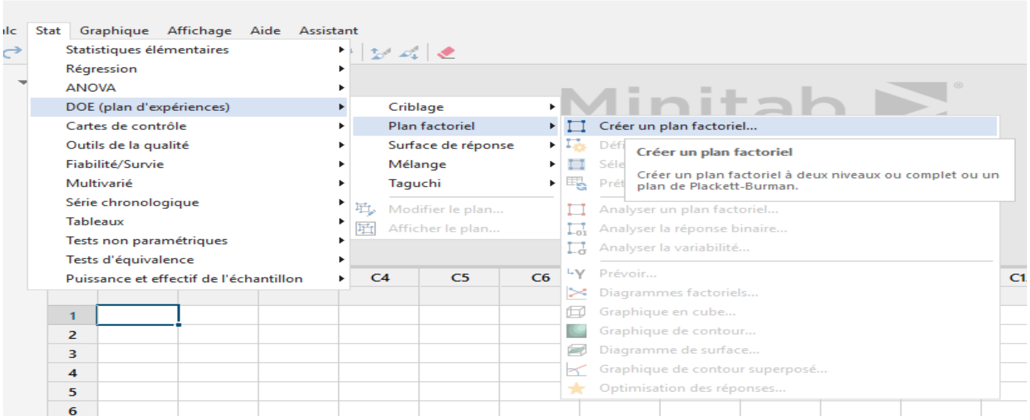


Figure 4: Main Window



↓	C1	C2	C3	C4	C5	C6	C7	C8
	Sol	Sucre	Temps de maturation	Sable	Résistance sec			
1	95	0	2	5	59,60			
2	95	0	4	5	74,30			
3	95	0	6	5	93,40			
4	95	0	8	5	97,10			
5	95	0	10	5	127,60			
6	95	0	12	5	130,80			
7	95	0	14	5	132,10			
8	90	5	2	5	61,05			
9	90	5	4	5	75,03			
10	90	5	6	5	102,10			
11	90	5	8	5	123,60			
12	90	5	10	5	135,00			
13	90	5	12	5	137,70			
14	90	5	14	5	138,60			
15	85	10	2	5	66,30			
16	85	10	4	5	78,70			
17	85	10	6	5	106,60			
18	85	10	8	5	134,20			
19	85	10	10	5	141,90			
20	85	10	12	5	143,80			
21	85	10	14	5	144,00			
22	80	15	2	5	60,60			
23	80	15	4	5	73,10			
24	80	15	6	5	102,90			
25	80	15	8	5	124,10			

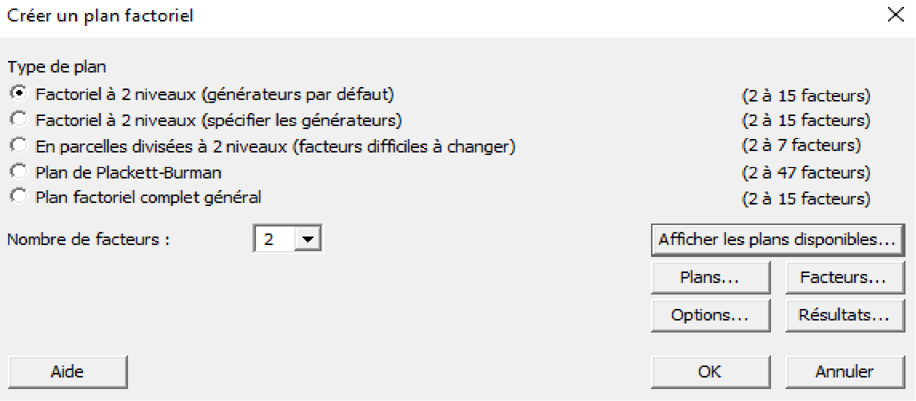
Figure 5: Main Window and Data



Créer un plan factoriel

Créer un plan factoriel à deux niveaux ou complet ou un plan de Plackett-Burman.

Figure 6: Design of Experiments Creation



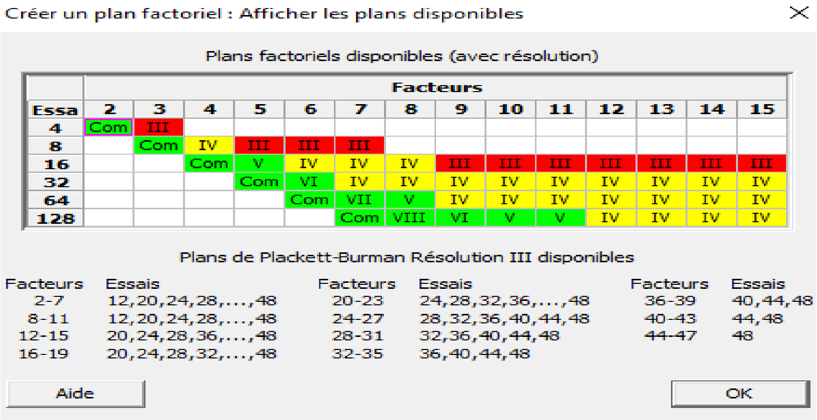
Créer un plan factoriel

Type de plan

● Factoriel à 2 niveaux (générateurs par défaut)	(2 à 15 facteurs)
○ Factoriel à 2 niveaux (spécifier les générateurs)	(2 à 15 facteurs)
○ En parcelles divisées à 2 niveaux (facteurs difficiles à changer)	(2 à 7 facteurs)
○ Plan de Plackett-Burman	(2 à 47 facteurs)
○ Plan factoriel complet général	(2 à 15 facteurs)

Nombre de facteurs : 2

Figure 7: Number of Factors Selection



Créer un plan factoriel : Afficher les plans disponibles

Plans factoriels disponibles (avec résolution)

	Facteurs													
Essa	2	3	4	5	6	7	8	9	10	11	12	13	14	15
4	Com	III												
8		Com	IV	III	III	III								
16			Com	V	IV	IV	IV	III	III	III	III	III	III	III
32				Com	VI	IV	IV	IV	IV	IV	IV	IV	IV	IV
64					Com	VII	V	IV	IV	IV	IV	IV	IV	IV
128						Com	VIII	VI	V	V	IV	IV	IV	IV

Plans de Plackett-Burman Résolution III disponibles

Facteurs	Essais	Facteurs	Essais	Facteurs	Essais
2-7	12,20,24,28,...,48	20-23	24,28,32,36,...,48	36-39	40,44,48
8-11	12,20,24,28,...,48	24-27	28,32,36,40,44,48	40-43	44,48
12-15	20,24,28,36,...,48	28-31	32,36,40,44,48	44-47	48
16-19	20,24,28,32,...,48	32-35	36,40,44,48		

Figure 8: Available Designs

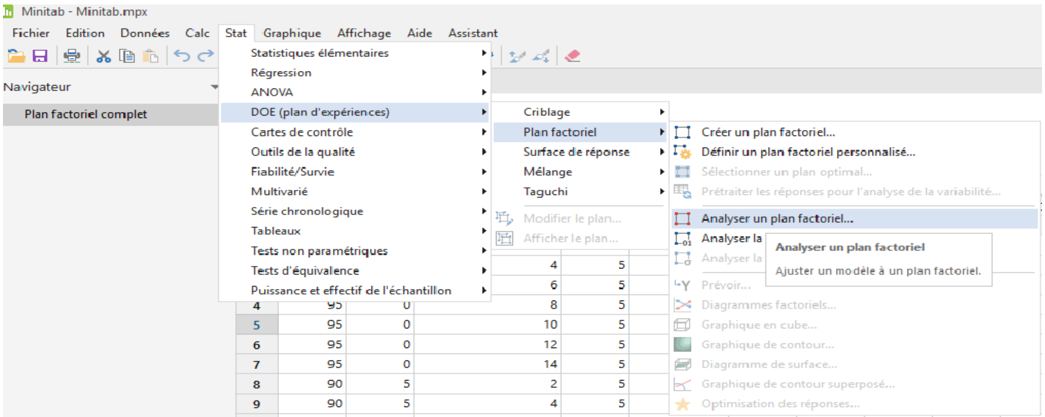
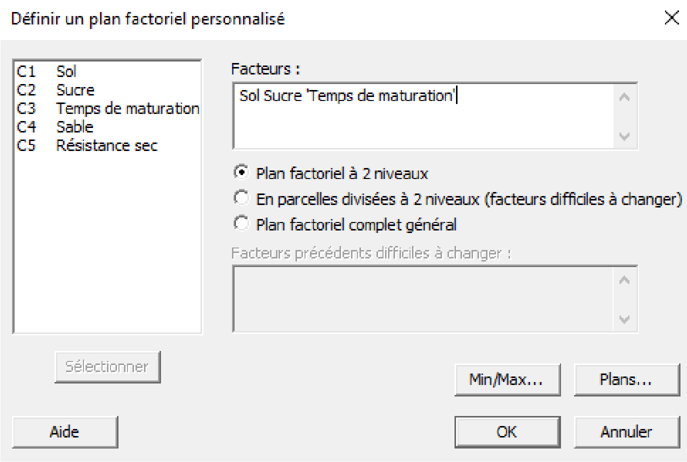


Figure 9: Analysis of a Factorial Design Selection



Définir un plan factoriel personnalisé

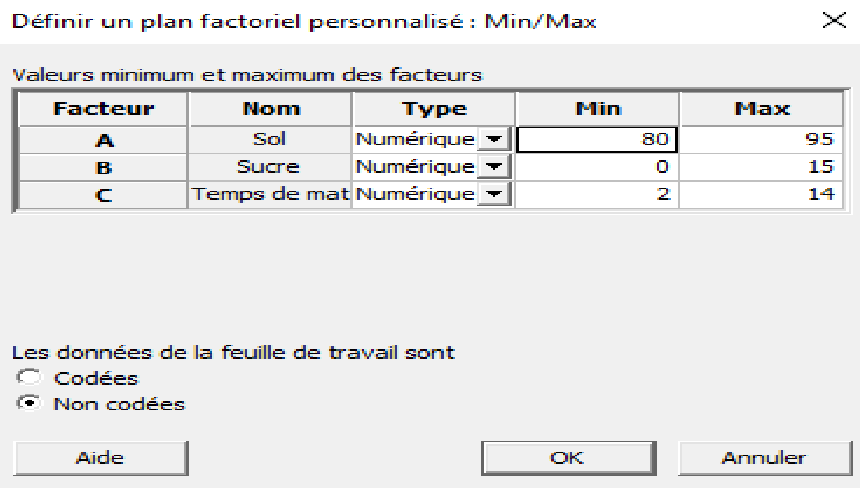
C1 Sol
C2 Sucre
C3 Temps de maturation
C4 Sable
C5 Résistance sec

Facteurs : Sol Sucre 'Temps de maturation'

● Plan factoriel à 2 niveaux
○ En parcelles divisées à 2 niveaux (facteurs difficiles à changer)
○ Plan factoriel complet général

Facteurs précédents difficiles à changer :

Figure 10: Defining a Factorial Design



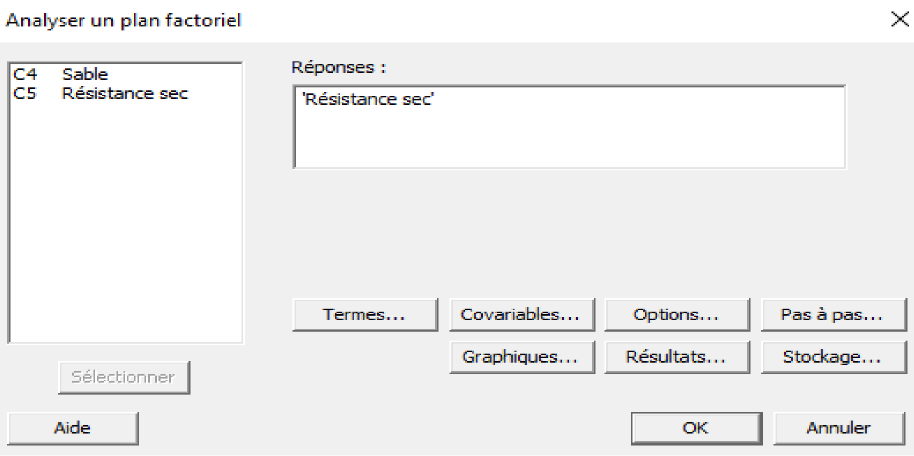
Définir un plan factoriel personnalisé : Min/Max

Valeurs minimum et maximum des facteurs

Facteur	Nom	Type	Min	Max
A	Sol	Numérique	80	95
B	Sucre	Numérique	0	15
C	Temps de mat	Numérique	2	14

Les données de la feuille de travail sont
○ Codées
● Non codées

Figure 11: Inputting Maximum and Minimum Values



Analyser un plan factoriel

C4 Sable
C5 Résistance sec

Réponses : 'Résistance sec'

Figure 12: Analysis of a Factorial Design

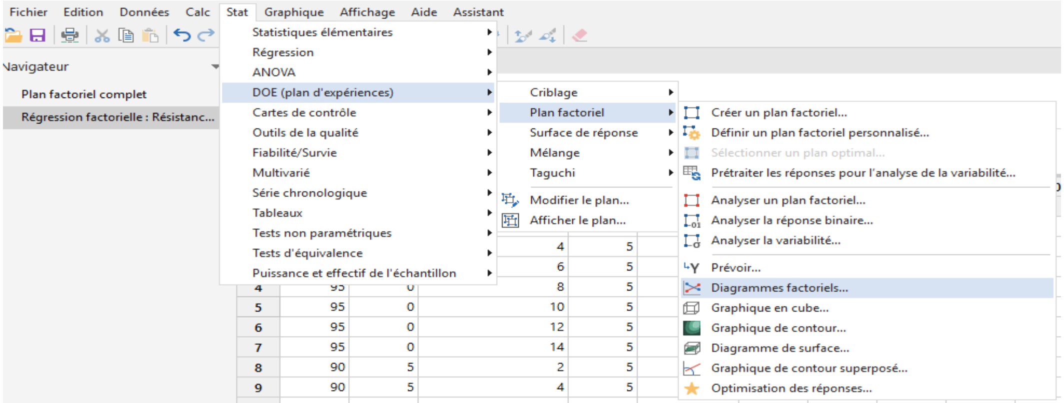
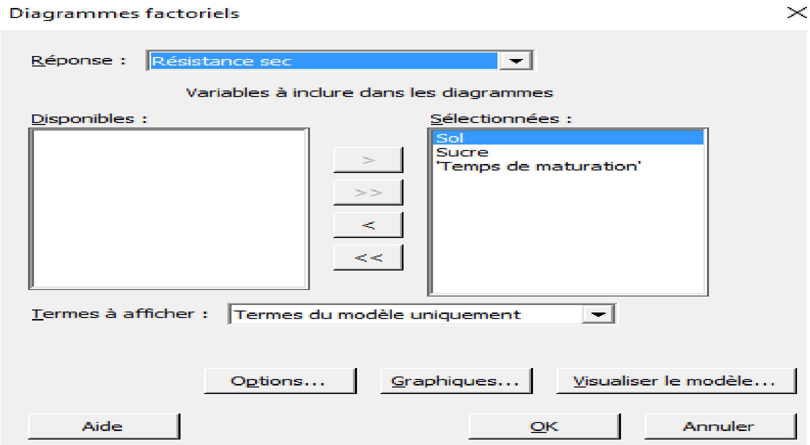


Figure 13: Factorial Plot

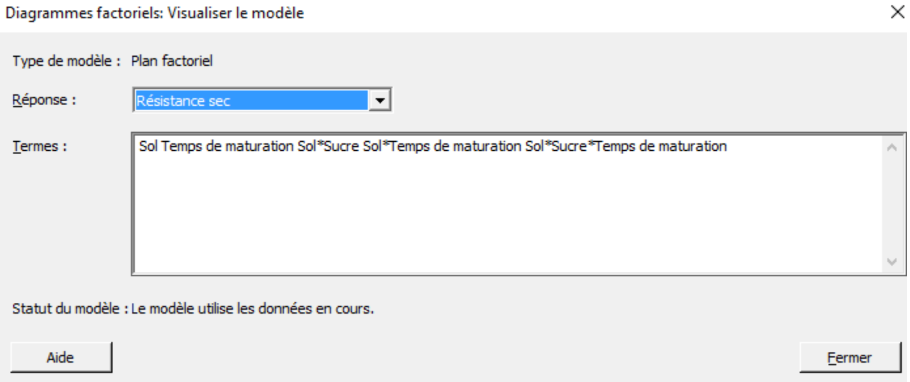


Réponse : Résistance sec

Sélectionnées :
Sol
Sucre
'Temps de maturation'

Termes à afficher : Termes du modèle uniquement

Figure 14: Factor Selection



Type de modèle : Plan factoriel

Réponse : Résistance sec

Termes : Sol Temps de maturation Sol*Sucre Sol*Temps de maturation Sol*Sucre*Temps de maturation

Statut du modèle : Le modèle utilise les données en cours.

Figure 15: Model Visualization

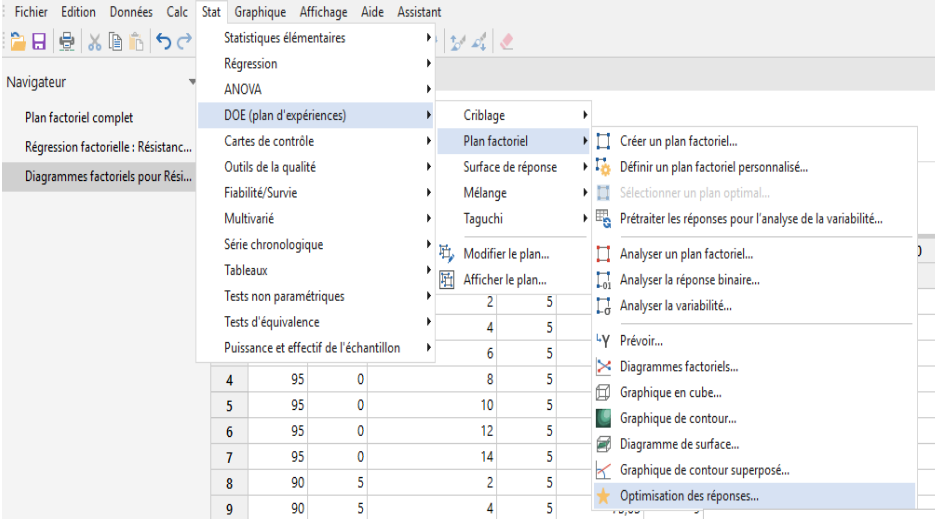
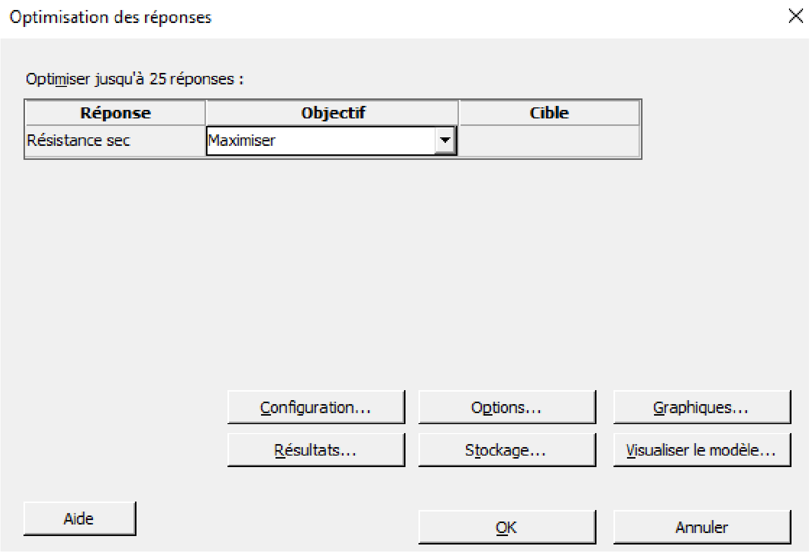


Figure 16: Response Optimization Creation



Optimiser jusqu'à 25 réponses :

Réponse	Objectif	Cible
Résistance sec	Maximiser	

Figure 17: Response Optimization

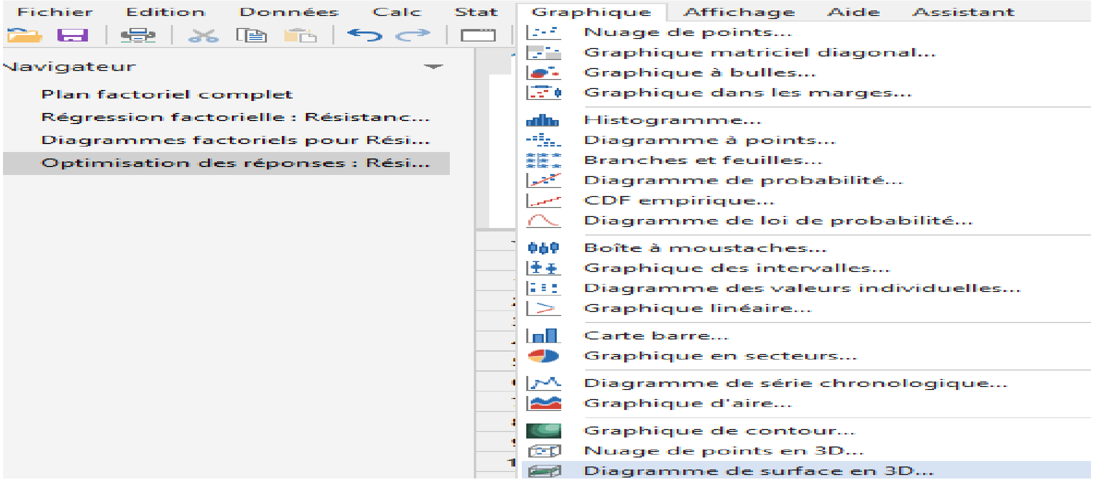


Figure 18: 3D Surface Plot Creation

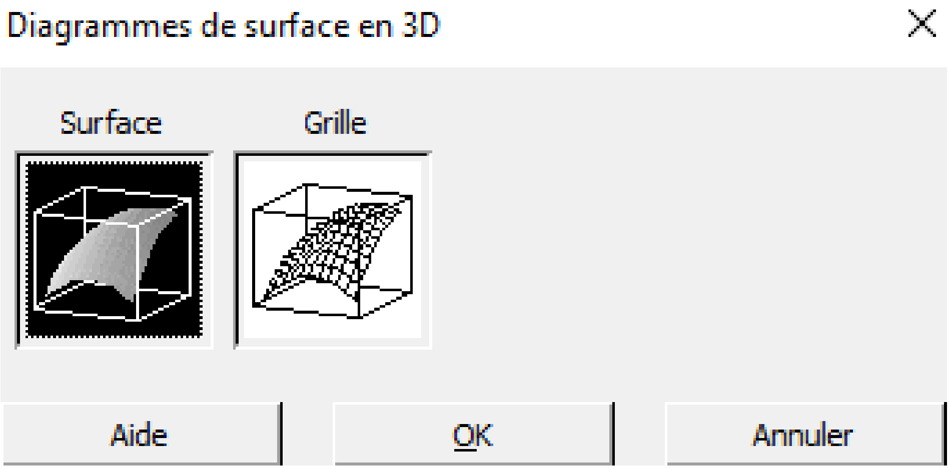
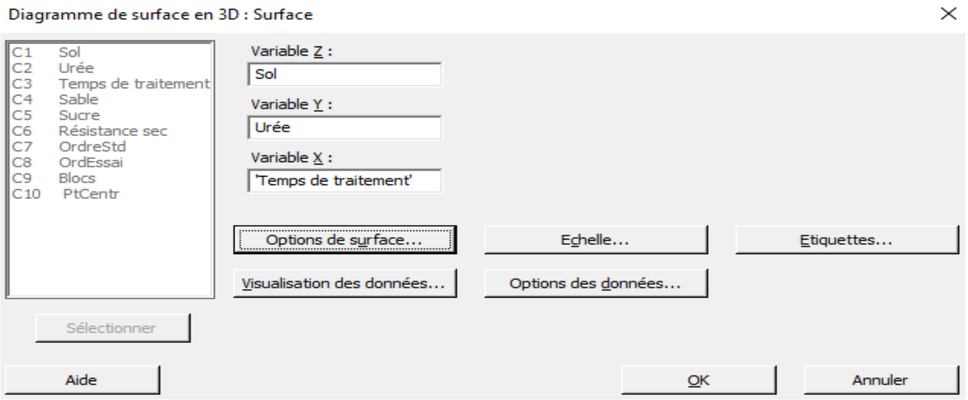


Figure 19: Surface Plot Selection



C1 Sol
C2 Urée
C3 Temps de traitement
C4 Sable
C5 Sucre
C6 Résistance sec
C7 OrdreStd
C8 OrdEssai
C9 Blocs
C10 PtCentr

Variable Z : Sol

Variable Y : Urée

Variable X : 'Temps de traitement'

Figure 20: Variable Selection for Surface Plot

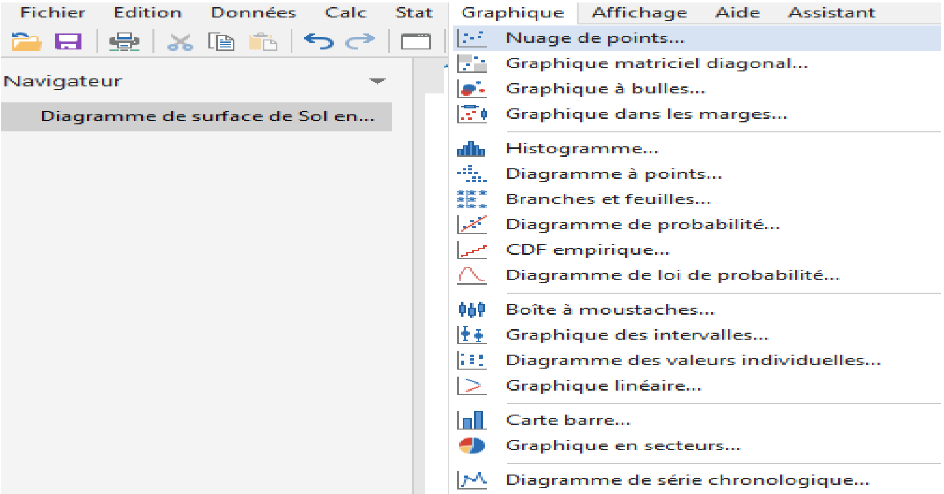


Figure 21: Scatter Plot Creation

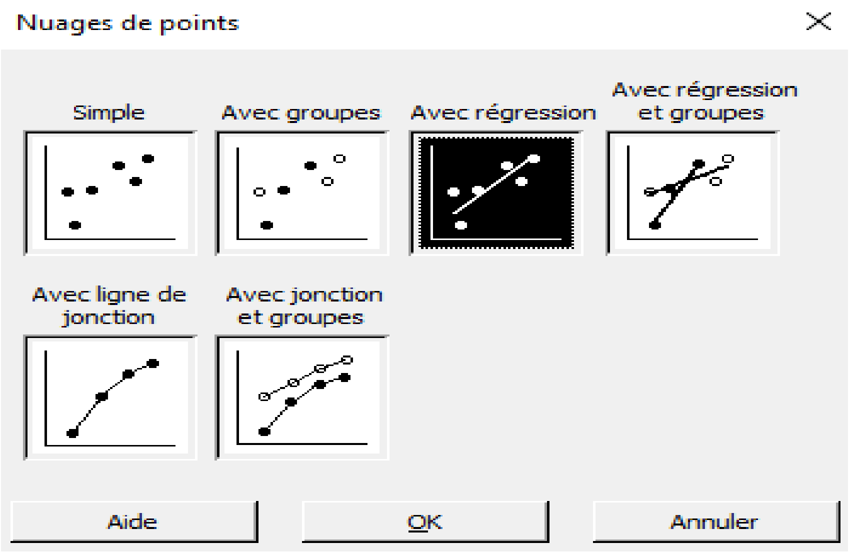
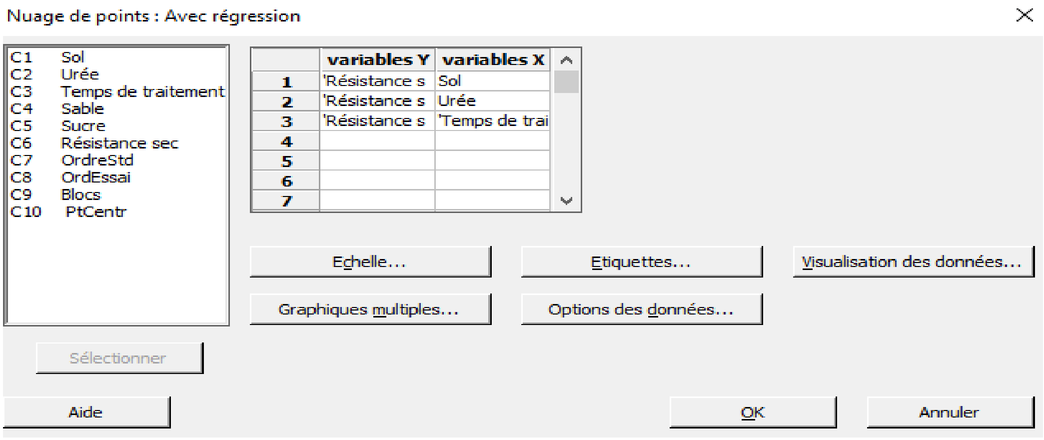


Figure 22: Scatter Plot Selection



C1 Sol
C2 Urée
C3 Temps de traitement
C4 Sable
C5 Sucre
C6 Résistance sec
C7 OrdreStd
C8 OrdEssai
C9 Blocs
C10 PtCentr

	variables Y	variables X
1	'Résistance s	Sol
2	'Résistance s	Urée
3	'Résistance s	'Temps de trai
4		
5		
6		
7		

Figure 23: Variable Selection for Scatter Plot

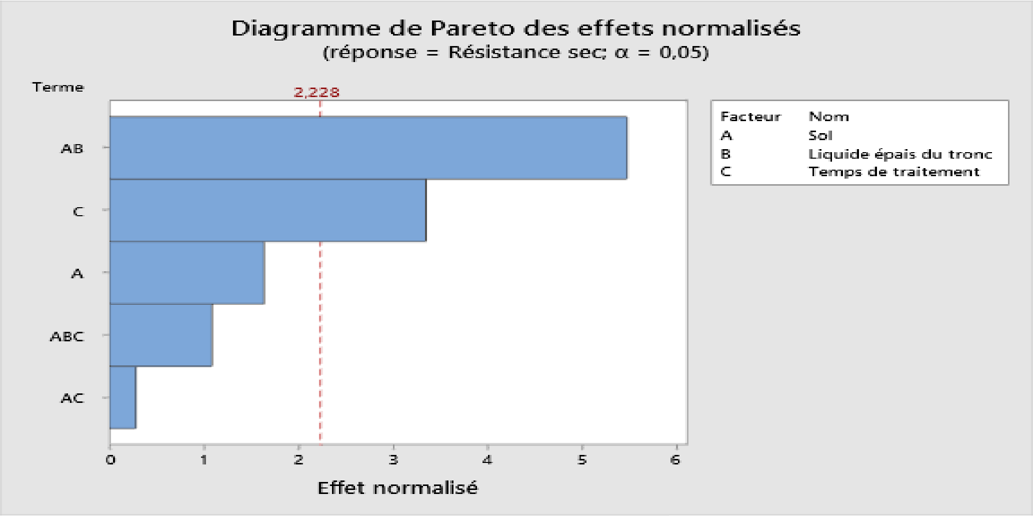


Figure 24: Pareto Chart

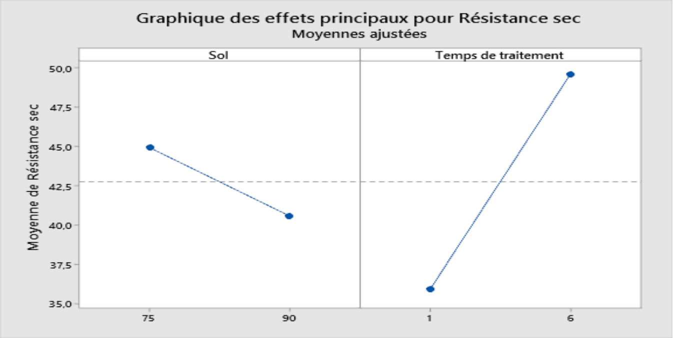


Figure 25: Main Effects Plot for Resistance

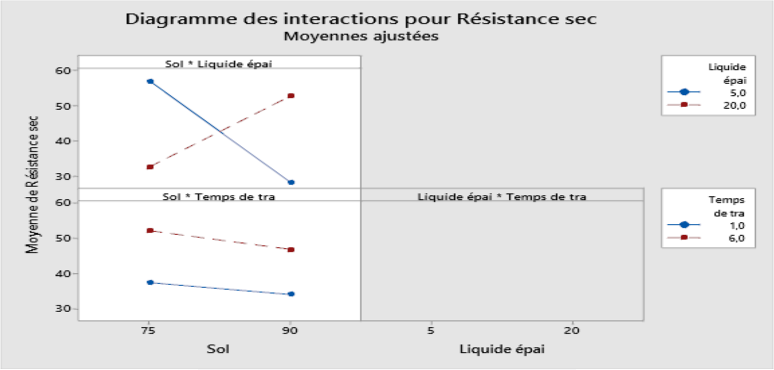


Figure 26: Interactions Plot

Figure 27: Response Optimization Plots for Resistance Rc sec with "Soil, Trunk, Treatment Time

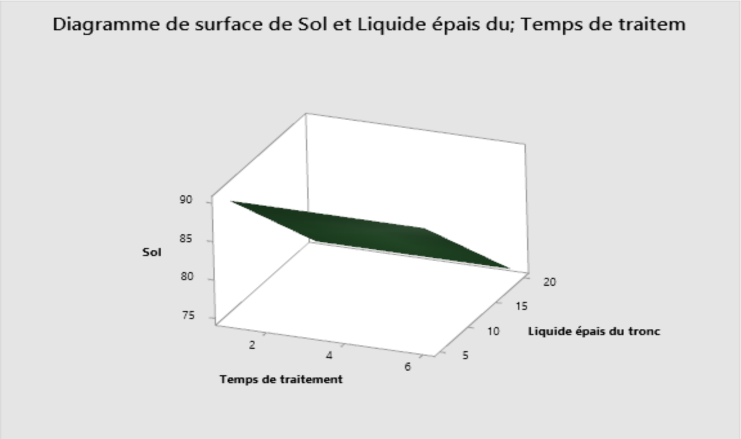


Figure 28: 3D Surface Plot of Resistance Rc sec with "Soil, Trunk, Treatment Time"

CONCLUSION

In summary, this study aims to achieve optimal consistency in the quality of compressed earth bricks. The main objective is to determine soil treatment using thick liquid extracted from the banana trunk, based on processing time. To achieve this, we employed the method of experimental design, leading to the attainment of optimal compression strength. The practical application of this approach has proven highly beneficial, providing valuable insights into the composition of compressed earth bricks.

The factors examined within this study are soil, trunk, and processing time. They were combined during brick fabrication with various levels (minimum, maximum) to identify statistically significant influencing parameters in the process. The Minitab software also played a pivotal role, employing linear regression to determine appropriate mathematical models for stabilizing the properties of compressed earth bricks in relation to the banana trunk. Verification of these adjusted models revealed regression coefficients of approximately 0.8, underscoring their reliability.

In conclusion, it would be relevant to continue validating the factors to consider in soil treatment using the banana trunk through experimental means. Processing time emerges as the factor with the greatest influence, but it would be wise to consider other parameters such as trunk and soil proportions for a deeper understanding of the process.

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