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Chamaerops humilis L. FRUIT PULP VALORIZATION: A DESIGN OF EXPERIMENTS APPROACH TO POWDER PRODUCTION AND PHYSICOCHEMICAL CHARACTERIZATION

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ABSTRACT

In response to demographic pressures and environmental imperatives, this study focuses on the valorization of *Chamaerops humilis* L. fruit in the Beni Mellal Khenifra region. The native palm, known as "Doum," holds nutritional and medicinal significance, prompting a detailed exploration. Extracts from its leaves and fruits have been historically used in traditional medicine, showcasing anti-oxidant properties and therapeutic effects on various ailments. This study seeks to optimize *Chamaerops humilis* L. fruit pulp powder production using the design of experiments (DOE) and physicochemical characterization. A full factorial design approach is applied to systematically optimize the process, focusing on key variables like Temperature and Time. Physicochemical analysis reveals essential details concerning pH (4.205), titratable acidity (1.47), moisture content (10.85%), and ash content (2.9325%). The study identifies optimal conditions, such as temperature = 65°C and time = 6 hours, for maximum yield and desirable properties. Additionally, water absorption (WAI) and solubility indices (WSI) are investigated, revealing the influence of drying and different agitation temperature. The Pareto diagram underscores the significant impact of these factors, contributing to our understanding of the quality parameters of *Chamaerops humilis* L. powder. The results offer valuable insights for sustainable practices in utilizing this botanical resource.

INTRODUCTION

In the face of increasing demographic pressures (WPP 2019), the need to develop innovative and sustainable approaches to exploiting natural resources has never been greater. This imperative is particularly relevant in the context of the Beni Mellal Khenifra region, where the valorization of the fruits of *Chamaerops humilis L.* presents itself as a promising trajectory, perfectly aligned with both economic requirements and environmental imperatives.

In recent years, there has been growing interest in exploring natural resources, particularly those from forest ecosystems, for their recognized nutritional and medicinal qualities (De Caluwé *et al.* 2010; Termote *et al.* 2010; Powell *et al.* 2015; Sevidzem *et al.* 2023). As part of this exploration, *Chamaerops humilis* L., familiarly known as Mediterranean palm or dwarf palm, emerges as a botanical treasure trove with versatile applications (El-Hilaly *et al.* 2003).

As a member of the Arecaceae family, this dioecious palm grows in the western Mediterranean region, north-west Africa and south-west Europe (García-Castaño *et al.* 2014; Guzmán *et al.* 2017). In Morocco, the native palm, known as "Doum", "Alghaz" or "Jmakh", has attracted attention for its nutritional and medicinal qualities (Medjati *et al.* 2019; Aboukhalaf *et al.* 2022; Derraji *et al.* 2023). Beyond its usefulness as a nutritional source in the diet (Nehdi *et al.* 2014), the constituents of *Chamaerops humilis* have a long history in traditional medicine (Bnouham *et al.*, 2010; Hasnaoui *et al.* 2011). The leaves, with their anti-oxidant properties and ability to inhibit lipoxygenase, have historically been used in the treatment of digestive disorders, spasms, diabetes and gastrointestinal problems (Bouhafsoun *et al.* 2019).

Numerous studies have highlighted the potential health benefits of eating *Chamaerops humilis* fruit, particularly in the management of conditions such as hyperlipidemia, obesity and hyperglycemia (Aissaoui *et al.* 2011). The "Doum" variant, in particular, has been attributed pharmacological properties, including anti-inflammatory, anabolic, antiseptic, urinary, antilithic and diuretic effects (Hasnaoui *et al.* 2011). Also, ethnobotanical research has led to a better understanding of the various applications of *Chamaerops humilis L.* in traditional medicine, highlighting its efficacy in the treatment of gastrointestinal disorders, prostate ailments and urinary tract infections (Aazza *et al.* 2014). In addition, *Chamaerops humilis* seed oil has been identified as a repository of unique fatty acids and substantial concentrations of tocotrienols and tocopherols (Bourkhiss *et al.* 2010).

In addition, the fruits and leaves of C. humilis L. abound in biologically active secondary metabolites such as tannins, phenols, saponins, flavonoids and terpenoids, which contribute substantially to the reported pharmacological effects, as attested by numerous studies (Bourkhiss *et al.* 2010; Aazza *et al.* 2014; Gonçalves *et al.* 2018). This study aims to further valorize and optimize *Chamaerops humilis L.* fruit pulp from Morocco, focusing specifically on powder production using design of experiments (DOE) and physicochemical characterization. The main objective is:

To contribute to the advancement of sustainable practices in the use of the fruits of *Chamaerops humilis L.* Through a detailed exploration of production processes, the study seeks to propose practices that align with environmental responsibility, ensuring the conservation of natural resources.

Design of experiments (DOE) is an efficient approach that allows researchers to systematically and simultaneously vary different factors (also known as independent variables) to understand their effects on a response variable. This approach is particularly valuable when studying multiple factors simultaneously, as it helps identify optimal conditions, predict outcomes, and understand the relationships between variables. DOE allows researchers to efficiently optimize processes, improve product quality, and understand how different factors interact and contribute to the desired outcomes. (Brisset *et al.* 2001). Focusing on key variables such as Temperature and Time aims to improve the efficiency of processing *Chamaerops humilis L.* fruit pulp into powder, adding a scientific dimension to resource use. Finally, the study aims to carry out a complete physicochemical characterization of the fruit pulp powder obtained. This analysis will provide valuable information on the powder's quality, composition and potential applications in various industries.

MATERIALS AND METHODS

Plant materials

The doum fruits from the *Chamaerops humilis L.* plant, were collected from an area of 1000 square meters in Bin El-Ouidane (Ouaouizght). This place is part of the Azilal province in the Beni Mellal Khenifra region. We did this in September 2021. Bin El-Ouidane is in the middle of the Atlas Mountains, about 1313 meters above sea level. Its location is at 32°05’ N latitude and 6°29’ W longitude (Lahssini *et al.* 2015).

This area has a semi-arid climate, meaning it experiences four seasons: winter, spring, summer, and autumn. It gets about 490 mm of rain every year, and the Temperature averages around 17.6 degrees Celsius. This information is summarized in Table (1) (Rahima *et al.* 2019). The harvested fruits were collected in well-closed boxes and stored in a dark and dry place, at Engineering and Applied Technologies Laboratory.

Table (1): Geographical and ecological characteristics of the fruit harvesting area

Region	Beni Mellal khenifra
Province	Azilal
City	Ouaouizeght
Harvesting area	Bin el-Ouidane
Geographic	Medium atlas
Climate	Semi-arid
Altitude	1313m
Latitude	32°05’ N
Longitude	6°29’ W
Annual precipitation	490 mm
Annual Temperature	17.6 C°

Methods

This work is part of valorizing and optimizing *Chamaerops humilis L.* fruit pulp, focusing specifically on powder production using (DOE). First, the pulp goes through different stages. It gets washed, pulled apart, and untangled. Finally, it's cut into small pieces. After that, we take 100 grams of these treated pieces and put them in an electric oven. The oven is set between 60 and 70 °C, and we leave the pieces in there for 4 to 8 hours (Mkaouar and Kechaou, 2013). To figure out the optimal conditions, we create a complete factorial plan of experiments. Once we have gone through all these steps, we analyze the dried and crushed pieces, along with the sieved powder, using various tests that check their physical and chemical properties.

Physicochemical analysis

pH

The pH is measured by directly immersing the electrode into the mixture. This involves heating a portion of the powder with distilled water in a water bath (AOAC, 1995).

Titratable acidity

The titratable acidity is determined by titration using a solution of sodium hydroxide (NaOH) in the presence of a colored indicator it is expressed in grams of acetic acid per 100 g of products (AOAC, 2000).

Moisture content

Moisture content was determined by drying 2 grams of powder in an oven at a temperature of 105°C until a constant mass of the sample was obtained (AOAC, 1997).

Ash content

The total ash content is obtained by completely calcining one gram of baked powder at 500°C for 4 hours in accordance with NFV 18-101 (AFNOR 1977b).

Water absorption and solubility indices

Water absorption index (WAI) is determined by the method of Anderson *et al.* In this procedure, 5 ml of distilled water was added to 0.2 g of powder placed in a tube. After 2 minutes of agitation at eight different temperatures (20°C, 30°C, 40°C, 50°C, 60°C, 70°C, 80°C, and 90°C), the aim was to examine the Temperature's impact on both indices. Subsequently, centrifugation was conducted for 15 minutes at 3000 rpm. The supernatant was evaporated, and the remaining gel was then weighed to complete the assessment gel (Nargis *et al.* 2017).

WAI was calculated as follows: WAI= mg/ mp

Where: mg is the weight of the hydrated gel (g) and mp is the weight of the sample (g).

For the solubility index (WSI) was determined from the amount of dry solids recovered by evaporation from the water absorption test supernatant (E Morsy *et al.* 2015).

WSI was calculated as follows: WSI= (mss/ mp) * 100

Where: mss is the weight of supernatant solids (g), and mp is the weight of sample (g).
mp is sample weight (g).

Design of Experiments

Design of Experiments (DOE) is a statistical technique used to systematically design, conduct, and analyze experiments in order to optimize processes, improve product quality, and understand the relationship between input variables (factors) and the output (response). DOE is particularly valuable for quickly and efficiently optimizing systems or processes (Goupy *et al.* 1996; Brisset *et al.* 2001). In our study, a full factorial design is a comprehensive experimental approach that systematically explores all possible combinations of factor levels in order to understand their collective impact on a response variable (Goupy. 1999). This design strategy is precious when studying multiple factors simultaneously. In our specific case, we are examining the influence of two factors: Temperature (measured in °C) and Time (measured in hours), on the response variables yield, pH, moisture content, ash content, and Titratable acidity.

In the introduction to a full factorial design, the factors are defined as follows:

- Temperature (Factor X1): This factor is varied between 60°C (low) and 70°C (high).
- Time (Factor X2): This factor is varied between 4 hours (low) and 8 hours (high).

The levels of each factor represent the specific values at which the factor is set. Temperature levels are categorized as 60°C (low) and 70°C (high). Similarly, for Time, the levels are characterized as 4 hours (low) and 8 hours (high) Table (2). Every possible combination of these factor levels is investigated in a full factorial design. In our case, with two factors, there are $2^2 = 4$ experimental runs. This systematic exploration allows for a comprehensive analysis of how Temperature and Time, at different levels, jointly influence the observed responses, which yield, pH, moisture content, ash content and Titratable acidity in this scenario.

Table (2): Factors and levels of full factorial design

Numbers of tests	Temperature	Time
1	-1	-1
2	+1	-1
3	-1	+1
4	+1	+1
Level -1	60	4
Level 1	70	8

Statistical Analysis

All the results were reported as means of triplicate analyses with the standard deviation (mean ± SD). Data analysis was performed utilizing analysis of variance (ANOVA) approach, with significant disparities between means identified at a confidence level of 95% ($p < 0.05$). All analysis was performed using JMP program (version JMP Pro 14).

RESULTS AND DISCUSSION

Table (3) presented below displays the experimental design along with the results of the physical-chemical characterization of the powder.

Table (3): Experimental design and results of physical-chemical characterization of powder

Essay	Temperature (X1)	Time (X2)	Yield (%)	pH	Moisture content (%)	Ash content (%)	Titratable acidity
C1	-1	-1	89%	4,19±0,24	11,5±0,5	3,1±0,23	1,52±0,15
C2	+1	-1	90%	4,19±0,35	10,4±0,71	2,8±0,35	1,5±0,29
C3	-1	+1	90%	4,24±0,15	11,5±0,62	3±0,7	1,4±0,18
C4	+1	+1	93%	4,2±0,75	10±0,77	2,83±0,21	1,46±0,32

The significance of p-values below 0.05 across all parameters Table (4) indicates that the factors temperature, Time, and their interaction significantly affect the responses (yield, pH, moisture content, ash content, and titratable acidity). These findings provide confidence in the model's predictive capability, suggesting that variations in Temperature and Time are associated with statistically significant changes in the studied responses (Marouane *et al.* 2016).

Table (4): Analysis of variance (ANOVA) Summary for response variables in a full factorial design. DF: degree of freedom

Yield (Y1)				
Term	Estimation	DF	Sum of squares	Judgment
Constant	90,5	-	-	Significant
Temperature (X1)	1	1	4	Significant
Time (X2)	1	1	4	Significant
Temperature*time	0,5	1	1	Significant

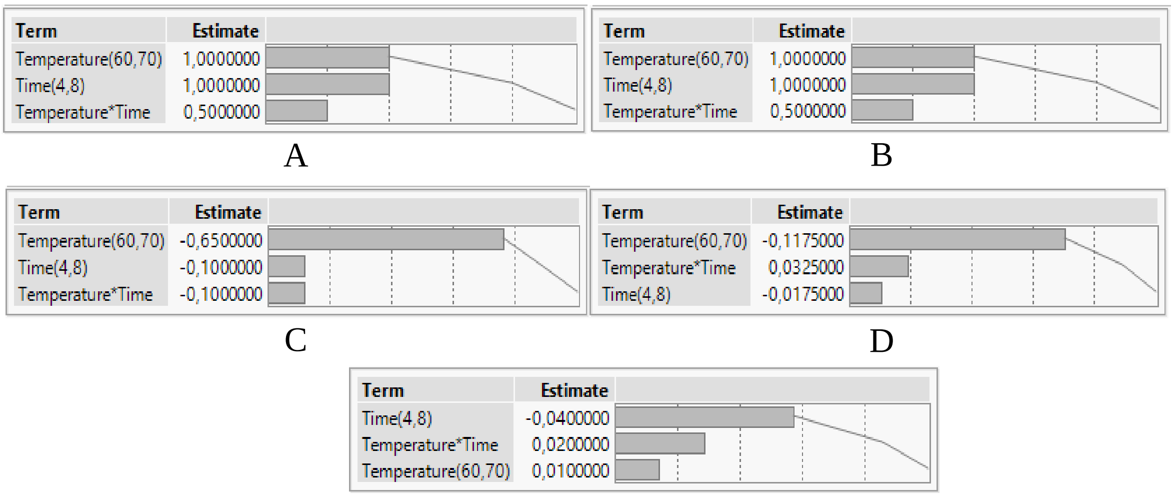
pH (Y2)				
Term	Estimation	DF	Sum of squares	Judgment
Constant	4,205	-	-	Significant
Temperature (X1)	-0,01	1	0,0004	Significant
Time (X2)	0,015	1	0,0009	Significant
Temperature*time	-0,01	1	0,0004	Significant
Moisture content (Y3)				
Term	Estimation	DF	Sum of squares	Judgment
Constant	10,85	-	-	Significant
Temperature (X1)	-0,65	1	1,69	Significant
Time (X2)	-0,1	1	0,04	Significant
Temperature*time	-0,1	1	0,04	Significant
Ash content (Y4)				
Term	Estimation	DF	Sum of squares	Judgment
Constant	2,9325	-	-	Significant
Temperature (X1)	-0,1175	1	0,0552	Significant
Time (X2)	-0,0175	1	0,0012	Significant
Temperature*time	0,0325	1	0,0042	Significant
Titratable acidity (Y5)				
Term	Estimation	DF	Sum of squares	Judgment
Constant	1,47	-	-	Significant
Temperature (X1)	0,01	1	0,0004	Significant
Time (X2)	-0,04	1	0,0064	Significant
Temperature*time	0,02	1	0,0016	Significant

The Pareto diagram, Figure (1), suggests that both Temperature and Time significantly affect Yield, pH, Moisture Content, and Ash Content. The longer bars for these factors indicate their relatively higher impact on these responses compared to other factors.

For Titratable Acidity, the diagram shows that Time and the interaction between Temperature and Time have longer bars, indicating greater significance in influencing titratable acidity than Temperature alone. This suggests that changes in Time and the combined effect of Temperature and Time have a more pronounced impact on titratable acidity.

Mathematical model

Determining factor coefficients and their interactions, coupled with assessing their statistical significance, enabled the development of predictive polynomial models. These models are represented by the corresponding equations for yield (Y1), pH (Y2), moisture content (Y3), ash content (Y4), and titratable acidity (Y5):



Term	Estimate
Temperature(60,70)	1,0000000
Time(4,8)	1,0000000
Temperature*Time	0,5000000

A

Term	Estimate
Temperature(60,70)	1,0000000
Time(4,8)	1,0000000
Temperature*Time	0,5000000

B

Term	Estimate
Temperature(60,70)	-0,6500000
Time(4,8)	-0,1000000
Temperature*Time	-0,1000000

C

Term	Estimate
Temperature(60,70)	-0,1175000
Temperature*Time	0,0325000
Time(4,8)	-0,0175000

D

Term	Estimate
Time(4,8)	-0,0400000
Temperature*Time	0,0200000
Temperature(60,70)	0,0100000

E

Figure (1): Pareto diagram for response variable in a full factorial design A: Pareto diagram of yield. B: Pareto diagram of Ph. C: Pareto diagram of moisture content. D: Pareto diagram of ash content. E: Pareto diagram of titratable acidity

$$Y1 = 90.5 + X1 + X2 + 0.5X1X2$$
$$Y2 = 4{,}205 - 0{,}01X1 + 0{,}015X2 - 0{,}01X1X2$$
$$Y3 = 10.85 - 0.65\ X1 - 0.1X2 - 0.1X1X2$$
$$Y4 = 2{,}9325 - 0{,}1175X1 - 0{,}0175X2 + 0{,}0325X1X2$$
$$Y5 = 1.47 + 0.01X1 - 0.04X2 + 0.02X1X2$$

These equations encapsulate the quantitative relationships between the independent factors (X1 and X2) and the respective responses. The coefficients within the equations signify the strength and direction of the influence of each factor and their interactions on the predicted values of the responses.

Optimal Conditions

The search for optimal operating conditions that led to optimizing parameters influencing the drying having optimal responses, based on previously established models, was done with the response profiler (Elmejhed *et al.* 2021). Figure (6) shows the results obtained.

Figure (2) indicates that achieving maximum efficiency requires an increase in Temperature and Time to the upper bound of the range of variation of these factors (70°C and 8h).

Our findings suggest that while an increase in Temperature may cause a slight increase in the acidity index of the powder, the prolongation of Time allows for a reduction in the acidity index. This is evidenced by the figure, which illustrates that the influence of Time is significant compared to Temperature. Importantly, this observation has not been reported in any prior works.

The drying temperature affects the pH, moisture and ash content of the powder. The latter are reached when the Temperature is in the upper limit (70°C).

To finalize the tests of the validity of the selected model, we used the test point tool with average desirability (0.5133) maximizes yield and titratable acidity and minimizes pH, moisture and ash content. Table (5) represents the optimum conditions that link the drying parameters to the responses.

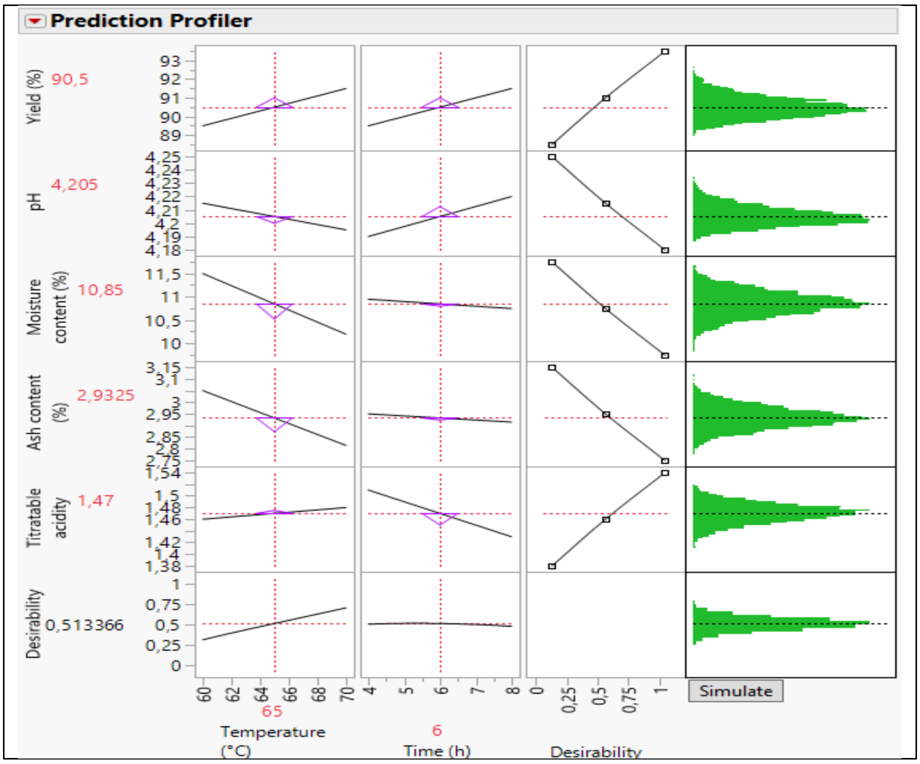


Figure (2): Forecast profile of optimum drying conditions for *Chamaerops humilis* L fruit.

Table3**):** predicted and experimental value for the test point

Parameter	¤ Optimal value	(%)	pH	Moisture content (%)	Ash content (%)	Acidity index
Temperature (°C)	65	90,5	4,205	10,85	2,9325	1,47
Time (h)	6					

Water absorption and solubility indices

The water absorption index (WAI) and the water solubility index (WSI) are critical parameters determining the quality of *Chamaerops humilis L.* powder.

A total of 32 experiments were conducted, covering all eight temperatures and both factors: Temperature (ranging from 60°C to 70°C) and Time (varied between 4 hours and 8 hours). Table (6) illustrates how drying conditions and tube temperature (Temperature during agitation) influence the development of the Water Absorption Index (WAI) and Water Solubility Index (WSI).

Table (6): drying condition effect and cooking condition on WSI and WAI

Essay	Drying Temperature	Drying Time	Tube temperature	WAI	WSI
C1	60°C	4 h	20°C	7,19	17,5
C2	70°C	4 h	20°C	7,18	19,6
C3	60°C	8 h	20°C	7,23	17,9
C4	70°C	8 h	20°C	7,12	18
C1	60°C	4 h	30°C	7,33	18,5
C2	70°C	4 h	30°C	7,15	20,5

Essay	Drying Temperature	Drying Time	Tube temperature	WAI	WSI
C3	60°C	8 h	30°C	7,14	20,1
C4	70°C	8 h	30°C	7,23	20
C1	60°C	4 h	40°C	7,55	22,3
C2	70°C	4 h	40°C	7,89	23,1
C3	60°C	8 h	40°C	7,53	21,8
C4	70°C	8 h	40°C	7,83	20,2
C1	60°C	4 h	50°C	7,82	28
C2	70°C	4 h	50°C	7,98	20
C3	60°C	8 h	50°C	7,73	29
C4	70°C	8 h	50°C	8,03	20,1
C1	60°C	4 h	60°C	8,21	23,3
C2	70°C	4 h	60°C	8,53	19,3
C3	60°C	8 h	60°C	8,21	21,9
C4	70°C	8 h	60°C	8,41	19
C1	60°C	4 h	70°C	8,87	24,3
C2	70°C	4 h	70°C	8,89	21,3
C3	60°C	8 h	70°C	8,77	23,2
C4	70°C	8 h	70°C	9,1	18,7
C1	60°C	4 h	80°C	8,89	19,7
C2	70°C	4 h	80°C	9,2	17,3
C3	60°C	8 h	80°C	8,98	19,2
C4	70°C	8 h	80°C	9,14	18,2
C1	60°C	4 h	90°C	9,10	17,5
C2	70°C	4 h	90°C	9,12	16,9
C3	60°C	8 h	90°C	8,99	18,2
C4	70°C	8 h	90°C	9,18	15,1

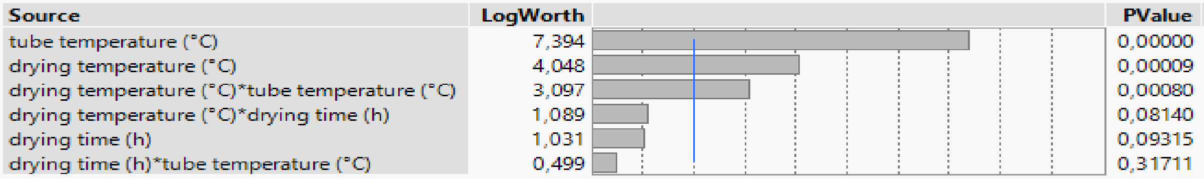
Table (7): WAI and WSI variance analysis.

Regression	WAI	WSI
N	32	32
Std Dev	0,7627	3,0056
Std Err Mean	0,1348	0,5313
Variance	0,5818	9,0338
C.V%	9,3334	14,8038
Interquartile range	1,5775	3,675
Robust standard devaition	0,804	2,6523
Median	8,1725	20,3031

N: number of tests; Std Dev: standard deviation; Std Err Mean: standard error mean; C.V: coefficient of variation

The variance analysis Table (7) provides insights into the distribution and variability of WAI and WSI data. WSI exhibits higher variability and a wider spread of values compared to WAI. The coefficient of variation, interquartile range, and median further elucidate the data distribution characteristics for each index.

The Pareto diagram in Figure (3) clearly shows that tube temperature (agitation temperature) has the most significant impact on Water Absorption Index (WAI) and Water Solubility Index (WSI). The influence of drying temperature is closely followed, and the interaction between drying temperature and tube temperature also plays a notable role. These factors, in the specified order, contribute significantly to the outcomes of WAI and WSI. The importance of these findings is supported by the p-values, all of which have $p<0.05$. This means that the observed effects are highly likely to be real and not due to random chance.



Source	LogWorth	PValue
tube temperature (°C)	7,394	0,00000
drying temperature (°C)	4,048	0,00009
drying temperature (°C)*tube temperature (°C)	3,097	0,00080
drying temperature (°C)*drying time (h)	1,089	0,08140
drying time (h)	1,031	0,09315
drying time (h)*tube temperature (°C)	0,499	0,31711

Figure (3): Pareto diagram of the interaction of two WAI and WSI responses

The Water Absorption Index (WAI) is the measure of the amount of water absorbed by starch, acting as an indicator of gelatinization. As depicted in Figure (4) left, the WAI notably increases with rising tube temperature (different agitation temperature). Additionally, there is a modest rise in WAI with an increase in drying temperature, aligning with findings from Table (3) that link moisture content to WAI increment. This observation is consistent with a study by Noha E. Morsy, which highlights thermal degradation during prolonged heating (E Morsy *et al.* 2015).

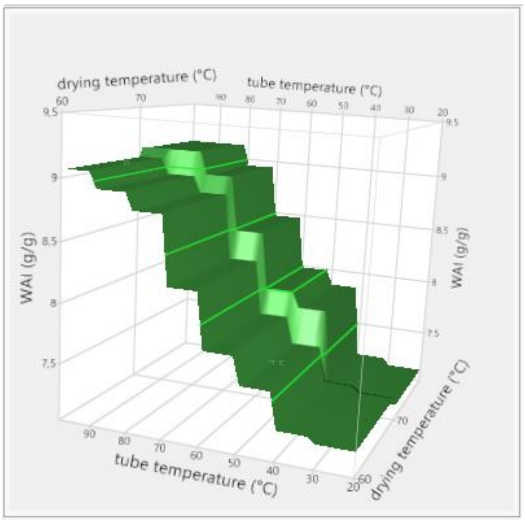


Figure (4): Effect of tube temperature and drying temperature on WAI

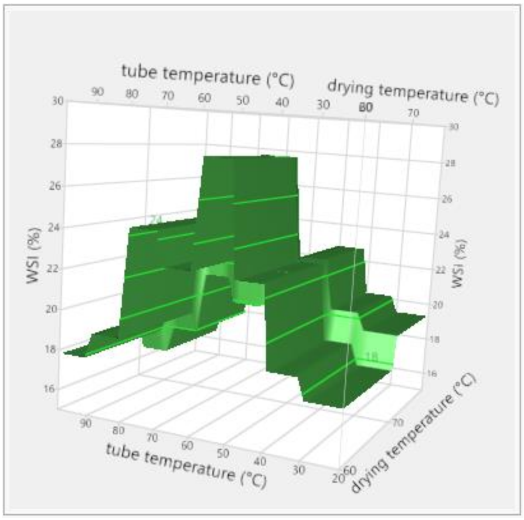


Figure (5): Effect of tube temperature and drying temperature on WSI

On the other hand, the Water Solubility Index (WSI), indicates molecular compound degradation and measures starch dextrinization during product cooking. Figure (5) illustrates that the solubility index increases with rising tube temperature until reaching a peak at cooking temperatures of 70°C. Subsequently, it declines with continued cooking (Temperature exceeding 70°C). A comparison with Table (3) reveals an inverse relationship between moisture content and the solubility index. This suggests that the increase in solubility index with higher cooking temperatures might be attributed to a similar variation in the lateral expansion of the extruded product (Nargis *et al.* 2017).

CONCLUSIONS

This comprehensive study on *Chamaerops humilis L.* fruit pulp powder production and characterization provide valuable insights into the optimization of processes and the quality parameters of this botanical resource. The exploration of the native palm's nutritional and medicinal qualities aligns with the increasing interest in sustainable exploitation of natural resources. Through systematic experimentation and statistical analysis, optimal conditions for powder production are identified at a temperature of 65°C and a duration of 6 hours. Physicochemical analysis reveals significant influences of Temperature and Time on yield, pH, moisture content, ash content, and titratable acidity. The developed predictive polynomial models enhance our understanding of the quantitative relationships between these factors and responses. The Pareto diagram emphasizes the pivotal role of Temperature and Time in shaping the characteristics of *Chamaerops humilis L.* powder. Water absorption and solubility indices contribute crucial insights into the quality of the powder. The study highlights the impact of drying and tube temperatures on these indices, providing a deeper understanding of gelatinization and starch dextrinization processes. In conclusion, this research contributes not only to the optimization of *Chamaerops humilis L.* fruit pulp powder production but also to the broader discourse on sustainable practices in utilizing natural resources. The findings offer a scientific basis for future endeavors in maximizing the benefits of this botanical treasure while ensuring environmental responsibility and conservation of natural resources.

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CONFLICT OF INTEREST

The researcher supports the idea that this work does not conflict with the interests of others.

تقييم لب فاكهة *Chamaerops humilis* L.: بنهج تصميم التجارب لإنتاج المسحوق والتوصيف الفيزيوكيميائي

حمزة الدراجي [1]، بدرالدين المجهد [2]، فوزية قزيبر [3]، وفاء الترووزي [4]
مختبر الهندسة والتقنيات التطبيقية، الكلية العليا للتكنولوجيا جامعة السلطان مولاي سليمان بني ملال، المغرب [1، 2، 3، 4]

الخلاصة

نتيجة للضغوط الديموغرافية والضروريات البيئية، ركزت هذا الدراسة على تحسين ثمار نخيل *Chamaerops humilis* L. في منطقة بني ملال خنيفرة. النخلة الأصلية، المعروفة باسم "الدوم"، والتي تحمل أهمية تغذوية وطبية، مما يدعونا إلى استكشاف مفصل. تم استخدام مستخلصات من أوراقها وثمارها تاريخيًا في الطب التقليدي، حيث تظهر خصائص مضادة للأكسدة وتأثيراتها العلاجية على أمراض متنوعة.

تسعى هذه الدراسة إلى تحسين إنتاج مسحوق لب ثمار *Chamaerops humilis* L. باستخدام تصميم التجارب (DOE) والتوصيف الفيزيوكيميائي. حيث يتم تطبيق نهج التصميم العاملي الكامل لتحسين العملية بشكل منهجي، مع التركيز على متغيرات رئيسية مثل درجة الحرارة والوقت. يوفر التحليل الفيزيوكيميائي رؤى حول الحموضة الحيوية، ومحتوى الرطوبة، ومحتوى الرماد. تحدد الدراسة الظروف المثلى لدرجة حرارة تساوي 65 درجة مئوية ووقت يساوي 6 ساعات للحصول على أقصى إنتاج. بالإضافة إلى ذلك، تم دراسة معامل امتصاص الماء (WAI) ومؤشرات الذوبان (WSI)، للكشف عن تأثير التجفيف ودرجات حرارة التقليب المختلفة. حيث يوضح مخطط باريتو التأثير الكبير لهذه العوامل، مما يساهم في فهمنا لمعايير الجودة لمسحوق *Chamaerops humilis* L.، اظهرت النتائج رؤى قيمة للممارسات المستدامة في استخدام هذا المورد النباتي.

الكلمات المفتاحية: تثمين، مسحوق، الفيزيائية والكيميائية، تصميم التجارب.

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