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Specialty: Toxicology

Them

Enhancing Chocolate Production with sugar Extracted from *Phoenix dactylifera Dates*

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Thanks

بسم الله الرحمان الرحيم

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Dedication

﴿وَقُل رَبِّ زِدْنِي عِلْمًا﴾

طه:(114)

All praise is due to Allah, through whose mercy this journey found its path, and by whose guidance every step was made possible.

I dedicate this humble work to those whose love, support, and prayers have been the foundation of my success:

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﴿رَبِّ ارْحَمْهُمَا كَمَا رَبَّيَانِي صَغِيرًا﴾

الإسراء:(24)

To my dear siblings: **Samira**, **Widad**, **Kamilia**, **Wassila**, **Abdelkarim**, **Abdelmoutalib**, **Abdeljalil**, and **Mohammed** thank you for your unwavering support and love.

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This accomplishment is yours as much as it is mine.

﴿وَمَا تَوْفِيقِي إِلَّا بِاللَّهِ ۚ عَلَيْهِ تَوَكَّلْتُ وَإِلَيْهِ أُنِيبُ﴾

هود:(88)

Asma Hamidi
Master's in Biology – Toxicology
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Dedication

All praise is due to Allah, first and last, outwardly and inwardly, by whose light I was guided, by whose grace I persevered, and through whose blessings this journey was crowned with success.
I dedicate this humble work to those whose presence in my life has been a true blessing, and whose support has been a constant source of strength:

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﴿ رَبِّ ارْحَمْهُمَا كَمَا رَبَّيَانِي صَغِيرًا ﴾
الإسراء (24)

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If this work holds any value, it is the fruit of the love, patience, and inspiration you have all planted in me.

﴿ وَمَا تَوْفِيقِي إِلَّا بِاللَّهِ ۚ عَلَيْهِ تَوَكَّلْتُ وَإِلَيْهِ أُنِيبُ﴾
هود (88)

Student: Benchaoui Sabrina
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بسم الله الرحمان الرحيم

﴿وَأَنْ لَيْسَ لِلْإِنْسَانِ إِلَّا مَا سَعَىٰ ﴿٣٩﴾ وَأَنَّ سَعْيَهُ سَوْفَ يُرَىٰ ﴾

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Abbreviation list

APGII	Angiosperm Phylogeny Group II
BCE	Before Common Era
DPP	Date Palm Pollen
EC	Electrical Conductivity
ETV	Electrothermal Vaporization
FAO	Food and Agriculture Organization
FTIR	Fourier Transform Infrared Spectroscopy
HPLC	High Performance Liquid Chromatography
IR	Infrared
LDL	Low-Density Lipoprotein
LRZA	Laboratoire de Recherche des Zones Arides
pH	Potential of Hydrogen
RT	Retention Time
USDA	United States Department of Agriculture
D.lcd	Deglet Beida lyophilized crude date
G.lcd	Ghars lyophilized crude date
N.lcd	Deglet Nour lyophilized crude date
D	Deglet Beida
G	Ghars
N	Deglet Nour
%	Percent
Mg	Milligram
G	Gram
Kg	Kilogram
mL	Milliliter
Cm	Centimeter
Mm	Millimeter
°C	Degrees Celsius
Ppm	Parts per million
Mg	Microgram
Kcal	Kilocalorie
Mm	Micrometer
cm^{-1}	Reciprocal centimeter (FTIR)

mS/cm	Millisiemens per centimeter
CE	Common Era
BCE	Before Common Era
EU	European Union
E 322	Phosphatidylcholine
GMO	Genetically Modified Organism
non-GMO	Non-Genetically Modified Organism
LDL	Low-Density Lipoprotein
HDL	High-Density Lipoprotein
SFA	Saturated Fatty Acids
PUFA	Polyunsaturated Fatty Acids
EEC	European Economic Community
ISO 9001	International Organization for Standardization 9001
ISO 22000	International Organization for Standardization 22000
β-cells	Beta cells
GLUT4	Glucose Transporter Type 4
ATP	Adenosine Triphosphate
PGC-1α	Peroxisome Proliferator-Activated Receptor Gamma Coactivator 1-alpha
DNA	Deoxyribonucleic Acid
CCAAT	CCAAT Box
mRNA	Messenger Ribonucleic Acid
kJ	Kilojoule
Rpm	Revolutions Per Minute
(w/v)	Weight/Volume
µL	Microliter

Abstract

This study aims to investigate and extract sugars from three local date varieties: **Degla Baida, Ghars, and Deglet Nour**, and to analyze their chemical and electrical composition as well as their impact on enhancing the sensory quality of chocolate sweetened with extracted date sugar. Date samples were collected from the **Djamaâ region, El M'Ghair Province (Algerian Sahara)**. Sugars were extracted using aqueous methods and analyzed through advanced techniques such as **FTIR, HPLC, and AAS** to determine chemical composition, mineral content, and structural characteristics of the sugars. Electrical conductivity analysis showed variation in total soluble salt content, with Deglet Nour exhibiting the highest salt concentration (1.92%), followed by Ghars (1.37%) and Degla Baida (0.94%), reflecting differences in ionic composition correlated with sugar content as confirmed by HPLC. FTIR spectroscopy revealed characteristic functional groups of sugars such as hydroxyl, carbonyl, and carbon-oxygen bonds, with the presence of both α and β anomers, influencing taste and sugar behavior in solutions. HPLC analysis demonstrated that Degla Baida had the highest total sugar content, dominated by fructose (48.5%), followed by glucose (43.3%) and a small amount of sucrose (8.2%). Ghars showed a high sucrose proportion (25%) alongside moderate glucose and fructose, while Deglet Nour had a high glucose content (72.6%) with no sucrose detected, indicating different ripening stages and enzymatic sugar conversion. Atomic absorption spectroscopy revealed variations in potassium, sodium, and calcium contents among the varieties, with Deglet Beida having the highest potassium level (0.066%), influencing the nutritional value of the extracted sugar. In chocolate making applications, sensory evaluations indicated that chocolate sweetened with Degla Baida sugar scored the highest in sweetness, flavor, overall acceptability, and stability due to its balanced sugar composition and low moisture content, which improved taste and texture. Chocolate with Ghars sugar had higher moisture and lower sensory acceptance due to its higher sucrose and reducing sugar levels, whereas Deglet Nour sugar resulted in the lowest sweetness and flavor scores despite high glucose content. These results highlight the importance of selecting the appropriate date variety for sugar extraction to improve the quality of food products such as chocolate, focusing on sugar composition, moisture content, and mineral elements to ensure balanced taste and stability.

Keywords:sugar extraction, Degla Baida, Ghars, Deglet Nour.

RÉSUMÉ

Ce travail vise à étudier et à extraire les sucres de trois variétés locales de dattes : **Degla Baida, Ghars et Deglet Nour**, ainsi qu'à analyser leur composition chimique et minérale, et à évaluer leur impact sur les propriétés sensorielles du chocolat sucré avec du sucre de dattes extrait. Les échantillons ont été collectés dans la **région de Djamaa, wilaya d'El M'Ghair, située au sud-est du Sahara algérien**. Les sucres ont été extraits par voie aqueuse, puis caractérisés à l'aide de techniques avancées telles que la **spectroscopie infrarouge à transformée de Fourier (FTIR), la chromatographie liquide à haute performance (HPLC), et la spectroscopie d'absorption atomique (AAS)**. Les résultats de la conductivité électrique ont révélé des différences notables dans la concentration en sels dissous, Deglet Nour enregistrant le taux le plus élevé (1,92 %), suivie de Ghars (1,37 %) et Deglet Beïda (0,94 %), reflétant une variation dans la composition ionique liée à la teneur en sucre, comme confirmé par les analyses HPLC. La spectroscopie FTIR a mis en évidence des groupes fonctionnels caractéristiques des sucres, notamment les hydroxyles, carbonyles, et les liaisons C-O, avec la présence de formes α et β, influençant le goût et la solubilité. L'analyse HPLC a montré que **Degla Baida** contenait la plus forte teneur en sucres totaux, dominée par le fructose (48,5 %), suivi du glucose (43,3 %) et du saccharose (8,2 %). Ghars a présenté une proportion notable de saccharose (25 %) accompagnée de fructose et de glucose, tandis que Deglet Nour se distingue par une très forte teneur en glucose (72,6 %) et l'absence totale de saccharose, traduisant une hydrolyse enzymatique avancée. L'analyse par spectroscopie d'absorption atomique a révélé des différences significatives dans les teneurs en potassium, sodium et calcium. Deglet Beïda présentait la teneur la plus élevée en potassium (0,066 %), soulignant sa valeur nutritionnelle potentielle. En application dans la fabrication du chocolat, les évaluations sensorielles ont montré que le chocolat sucré avec le sucre de **Degla Baida** obtenait les meilleurs scores en termes de douceur, de goût et d'acceptabilité, grâce à une composition sucrière équilibrée et une faible humidité. Le chocolat à base de **Ghars** a présenté une humidité élevée et une acceptabilité sensorielle modérée, affectée par une forte teneur en sucres réducteurs et saccharose. En revanche, celui préparé avec **Deglet Nour** a obtenu les scores les plus faibles, en raison de l'absence de composés aromatiques distinctifs. Ces résultats mettent en évidence l'importance du choix de la variété de dattes dans l'extraction du sucre destiné à l'industrie alimentaire, notamment pour améliorer la qualité organoleptique des produits comme le chocolat, en se basant sur la composition en sucres, l'humidité et les minéraux.

Mots-clés :extraction du sucre, Degla Baida, Ghars, Deglet Nour,

الملخص

يهدف هذا العمل إلى دراسة واستخلاص السكريات من ثلاث أصناف محلية من التمور: الدقلة البيضاء، الغرس، ودقلة نور، وتحليل تركيبها الكيميائي والمعدني، بالإضافة إلى تقييم تأثيرها على الخصائص الحسية للشوكولاتة المحلّاة بسكر التمر المستخلص. تم جمع عينات التمور من منطقة جامعة بولاية المغير الواقعة في جنوب شرق الصحراء الجزائرية. تم استخلاص السكريات بطريقة مائية، وتشخيصها باستخدام تقنيات متقدمة مثل التحليل الطيفي بالأشعة تحت الحمراء FTIR، الكروماتوغرافيا السائلة عالية الأداء HPLC، والتحليل الطيفي بالامتصاص الذري AAS لتحديد التركيب الكيميائي والمعدني، والخصائص البنيوية للسكريات. أظهرت نتائج التوصيلية الكهربائية اختلافاً في تركيز الأملاح الذائبة، حيث سجلت دقلة نور أعلى نسبة (١.٩٢%)، تلتها الغرس (١.٣٧%) ثم الدقلة البيضاء (٠.٩٤%)، ما يعكس اختلاف التركيب الأيوني المرتبط بمحتوى السكر كما أكده تحليل HPLC. أظهر التحليل الطيفي FTIR وجود مجموعات وظيفية مميزة للسكريات مثل الهيدروكسيل والكربونيل وروابط الكربون-أكسجين، مع وجود شكلي ألفا وبيتا للسكريات، مما يؤثر على المذاق وسلوك السكر في الوسط الغذائي. أظهر تحليل HPLC أن الدقلة البيضاء تحتوي على أعلى نسبة سكريات إجمالية، تتكون أساسًا من الفركتوز (٤٨.٥%)، يليه الغلوكوز (٤٣.٣%) ثم السكروز بنسبة ضئيلة (٨.٢%). بينما أظهرت الغرس نسبة سكروز مرتفعة (٢٥%) مع محتوى معتدل من الفركتوز والغلوكوز، أما دقلة نور فتميزت بنسبة غلوكوز عالية (٧٢.٦%) دون وجود للسكروز، ما يشير إلى تقدم في نضج الثمار وتحلل السكروز بفعل الإنزيمات. أما التحليل الطيفي بالامتصاص الذري فقد كشف عن اختلافات في نسب البوتاسيوم والصوديوم والكالسيوم، حيث سجلت الدقلة البيضاء أعلى نسبة بوتاسيوم (٠.٠٦٦%)، مما يعكس أهمية هذه الأصناف من حيث قيمتها الغذائية. في تطبيقات صناعة الشوكولاتة، أظهرت التقييمات الحسية أن الشوكولاتة المحلّاة بسكر الدقلة البيضاء سجلت أعلى الدرجات من حيث الحلاوة والنكهة والقبول العام، ويُعزى ذلك إلى توازن مكوناتها السكرية وانخفاض محتوى الرطوبة، ما ساهم في تحسين المذاق والقوام. أما شوكولاتة الغرس فقد تميزت برطوبة مرتفعة وقبول حسي أقل بسبب ارتفاع السكريات المختزلة والسكروز. في المقابل، سجلت شوكولاتة دقلة نور أدنى التقييمات الحسية رغم محتواها العالي من الغلوكوز، نتيجة غياب مركبات النكهة والعطر. تؤكد هذه النتائج أهمية اختيار صنف التمر المناسب لاستخلاص السكر بهدف تحسين جودة المنتجات الغذائية مثل الشوكولاتة، من خلال التركيز على تركيبة السكريات، محتوى الرطوبة، والعناصر المعدنية لضمان نكهة متوازنة واستقرار في المنتج النهائي.

الكلمات المفتاحية: استخلاص السكر، الدقلة البيضاء، الغرس، دقلة نور.

Introduction

Introduction

The human body constantly needs food to meet its vital requirements and maintain its basic physiological functions. A balanced diet consists of key components such as carbohydrates (sugars), proteins, fats, minerals, and vitamins, each playing a specific role in supporting bodily functions. Sugars, especially sucrose, are considered among the most important quick sources of energy. Inside the body, they are breaked into glucose, which is directly used in cellular processes, particularly in the brain and muscles. Therefore, the body's demand for sugars increases more than for other nutrients, especially during periods of intense physical or mental activity. Sugar is a fundamental food substance that is incorporated into a wide range of food products and beverages and is consumed daily by various population groups. Sugars, particularly sucrose, are mainly extracted from two key agricultural sources: sugarcane and sugar beet, which together account for over 90% of global sugar production **(A.M. Contreras *et al.*, 2009)**. Although sugar is classified as a food commodity, its economic and strategic significance has elevated it to a globally traded resource alongside vital commodities such as oil and gold **(ANON, 2016)**.However, refined sugar faces several challenges, the most prominent being its health impacts. Refined sugar faces several challenges, the most prominent being its health impacts. According to the World Health Organization (WHO, 2015), excessive sugar consumption has been linked to chronic diseases such as obesity, type 2 diabetes, and dental caries. This is primarily due to its high caloric content and lack of essential nutrients, often referred to as "empty calories.". Environmentally, sugar cultivation requires large amounts of water and leads to soil degradation, while industrial refining processes consume significant energy and generate polluting waste. Economically, the global sugar market suffers from fluctuations in supply and demand, often causing price increases, especially in non-producing countries. In the Arab world, most countries still rely on sugar imports to meet their needs, with annual imports estimated at around 3.3 million tons, valued at approximately 1.3 billion USD. Although regional production increased from 2.1 million tons in 1993 to 2.52 million tons in 2000, then to 4.5 million tons in 2020, and nearly 5 million tons by 2024 (Index Box), this growth remains insufficient to meet rising demand, according to USDA reports (2024). In Algeria, which does not produce sugarcane or sugar beet, raw or liquid sugar is imported and refined locally. In 2015, sugar imports reached 1.92 million tons at a cost exceeding 714.76 million USD **(Bensassi, S, 2017; AOAD, 2014)**. Although Algeria ranked third in sugar production

in the Arab world with a total of 848,000 tons in 2013 **(AOAD, 2014)**, this production is entirely dependent on imported raw materials.

Chocolate is valued for its sensory appeal and potential health benefits, particularly when rich in cocoa. Its antioxidant and cardioprotective properties are mainly attributed to flavonoids and polyphenols **(Katz *et al.*, 2011)**. However, most commercial chocolates contain high amounts of refined sugar, which is linked to obesity, insulin resistance, and other health risks. Using natural sugar alternatives may help preserve the benefits of chocolate while minimizing these negative effects. Algerian dates are rich in simple sugars such as fructose, glucose, and sucrose, making them a promising source for natural sugar production**(Sidab, 2016;Chouicha, 2014).** Algeria lacks advanced technologies to convert dates into high-value products, as the industry is mostly limited to packaging and paste production. This highlights the need to develop modern extraction methods to fully utilize the potential of dates and reduce dependency on imports. A global trend toward healthier alternatives to refined white sugar.

The objective of this study is to extract water-soluble sugars from three varieties of *Phoenix dactylifera* dates (Ghrass, Deglet Nour, and Degla Bayda) and to evaluate the efficiency of each variety for use in producing healthier and better-tasting chocolate as a natural alternative to refined sugar. The study is divided into two main parts. The theoretical part consists of two chapters: the first provides an overview of *Phoenix dactylifera* dates, including their origin, botanical characteristics, and the specific features of the selected varieties; the second focuses on chocolate production, detailing the manufacturing stages and the role of sweeteners in it formulation. The experimental part includes the third chapter, which describes the methodology used for sugar extraction from the dates, including the tools, materials, and procedures, as well as how the extracts were prepared for use in chocolate production. The fourth chapter presents and discusses the results, highlighting the differences between the varieties in terms of sugar content and their impact on chocolate quality. The study concludes with a conclusion and recommendations for future research and practical applications in the food industry.

First part

BibliographicPART

Chapter I: *Phoneix Dactylifera*

I- *Phoenix dactylifera*

I.1. classification of *phoenix dactylifera*:

The palm family is scientifically known as Palmaceae, but according to modern botanical nomenclature rules, its name was later changed to Arecaceae, derived from the genus Areca, one of the largest genera within this family. Palms belong to the order Arecales, one of the most significant plant orders known to humans. They are classified under the class Monocotyledonae (monocots) within the subdivision Angiospermae (angiosperms), which belongs to the division Tracheophyta (vascular flowering plants)**(Owda, 2011).**

Table 01: Classification of arecaceae within the Angiosperm class according to the third group system of Angiosperm phylogeny **(APGIIl, 2003; Sannier 2006)**

Kingdom	**Plantae (Plant)**
Division	Tracheophyta (Vascular plants)
Subdivision	Angiospermae (Angiosperms)
Class	Monocotyledonae (Monocots)
Order	Arecales
Family	Arecaceae (Palm family)
Genre	*Phoenix*
Species	*Phoenix dactylifera* linnaeus

I.2. Geographical Distribution of *phoenix dactylifera:*

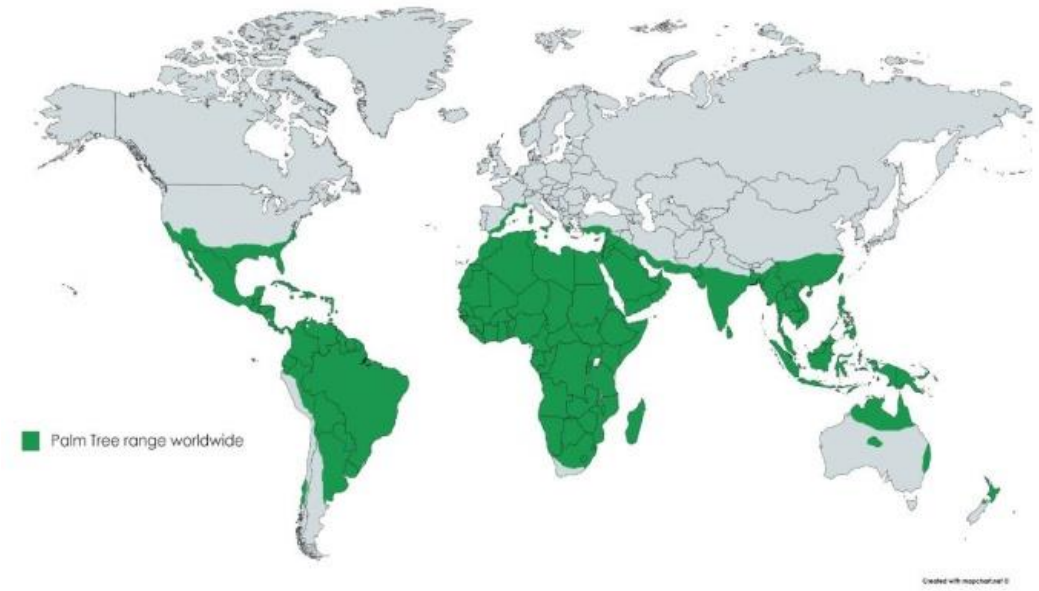
I.2.1. GlobalDistribution :

The date palm (*Phoenix dactylifera*) has been cultivated since ancient times in arid and semi-arid regions, with its cultivation spreading globally through historical migrations. Arab traders played a pivotal role in introducing the crop to East Africa in the 15th century, followed by Madagascar in the 17th century.

During the 19th century, date palm cultivation expanded to Australia and subsequently to parts of Southern Europe and the Americas **(Amorsi, 1975).**

Leter, date palms are widely grown across most Arab countries, particularly thriving in desert environments characterized by dry climatic conditions that are ideally suited for their growth.

This geographical distribution reflects both the historical trade routes and the plant's remarkable adaptation to harsh, water-limited ecosystems **(Ahmed, 2005).**



Population of the Date Palm

Figure 01: Map of Geographic Distribution of the Date Palm Worldwide **(EL HADRAMI 2009)**

Global date production is approximately 7 million tons per year and has more than doubled since the 1980s **(FAO, 2010).** This places dates in the 5th position among the most produced fruits in arid and semi-arid regions.According to the **(**FAO **2018),** global date production is estimated at 8,166,814 tons (Figure 2).

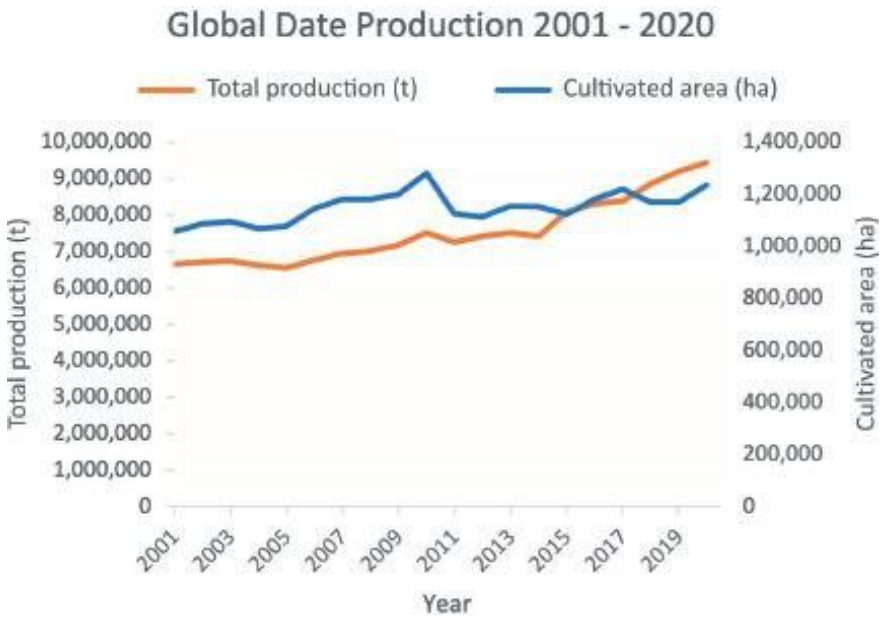


Figure02: Global Date Production**(FAO 2018)**

I.2.2. Distribution of *phoenix dactylifera* in Algeria:

According to the latest statistics from the Ministry of Agriculture and Rural Development **(2015),** date palm cultivation in Algeria covers an area of approximately 169,000 hectares, with an estimated 18 million palm trees.

The production of dates across all varieties is estimated at around 995,000 tons. Date palm cultivation is primarily concentrated in the well-known regions of the south and the Sahara, spanning 19 provinces (in reality, only 10 provinces if areas that have lost their suitability for date palm cultivation are excluded).

The province of Biskra ranks first, accounting for 29.4% of the total cultivated area, 21.1% of the total number of palm trees, and 41.2% of the national date production.It is followed by El Oued province, which accounts for 22% of the area, 22.4% of the number of trees, and 20% of the production. Together, these two provinces account for two-thirds (2/3) of the national date production. Distribution of Date Palm Cultivation by Province

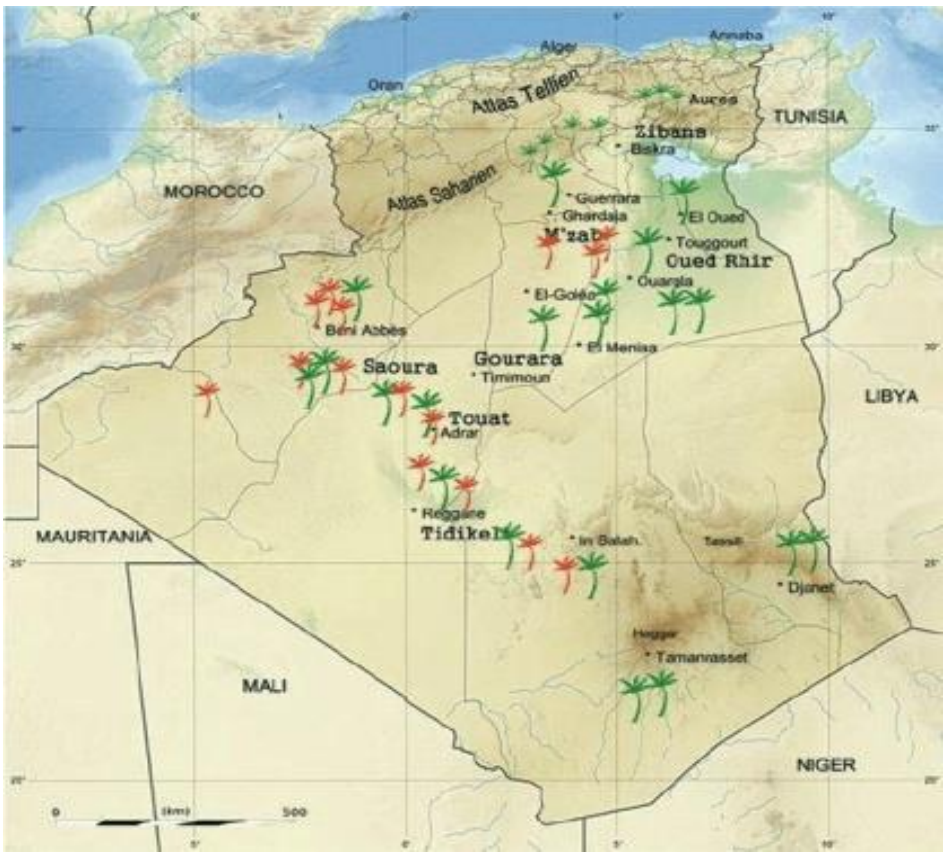


Figure 03: Map of Algeria indicating the different areas with date palms; those in red are bayoud infested, those in green not infested **(Source: N. Bouguedoura Research Laboratory of Arid Areas (LRZA);2015)**

Production is estimated at 492,217 tons, including: - 244,636 tons (50%) of semi-soft dates (Deglet Nour), - 164,453 tons (33%) of dry dates (Degla Beida and similar varieties), - 83,128 tons (17%) of soft dates (Ghars a nd similar varieties).The Algerian palm grove consists of over 11 million palm trees spread across 9 Saharan provinces: Biskra, El-Oued, Ouargla, Ghardaia, Adrar, Béchar, Tamanrasset, Illizi, and Tindouf.

The date palm is also found in other provinces located in transitional zones between the steppe and the Sahara, which are considered "marginal" compared to Saharan palm groves **(BELGUEDJ, 2007).** Currently, date production has nearly doubled, increasing from 600,096 tons in 2012 to approximately 1,100,000 tons in 2017, with only 3% being exported. Algeria is ranked among the world's leading date producers (4th globally, with 14% of global production). However, the export value in 2016 was $37 million, which is considered insignificant compared to the existing potential **(Algerian Chamber of Commerce and Industry, 2017).** According to FAO **(2018),** Algeria's national date production was estimated at 1,058,559 tons, with a yield of 63.136 kg per palm tree. The total area cultivated with date

palms in Algeria covers 167,663 hectares (Figure 3), with significant variations between provinces. The largest cultivation areas are concentrated in the provinces of Biskra and El-Oued, which together account for 52% of the total date palm plantation area.

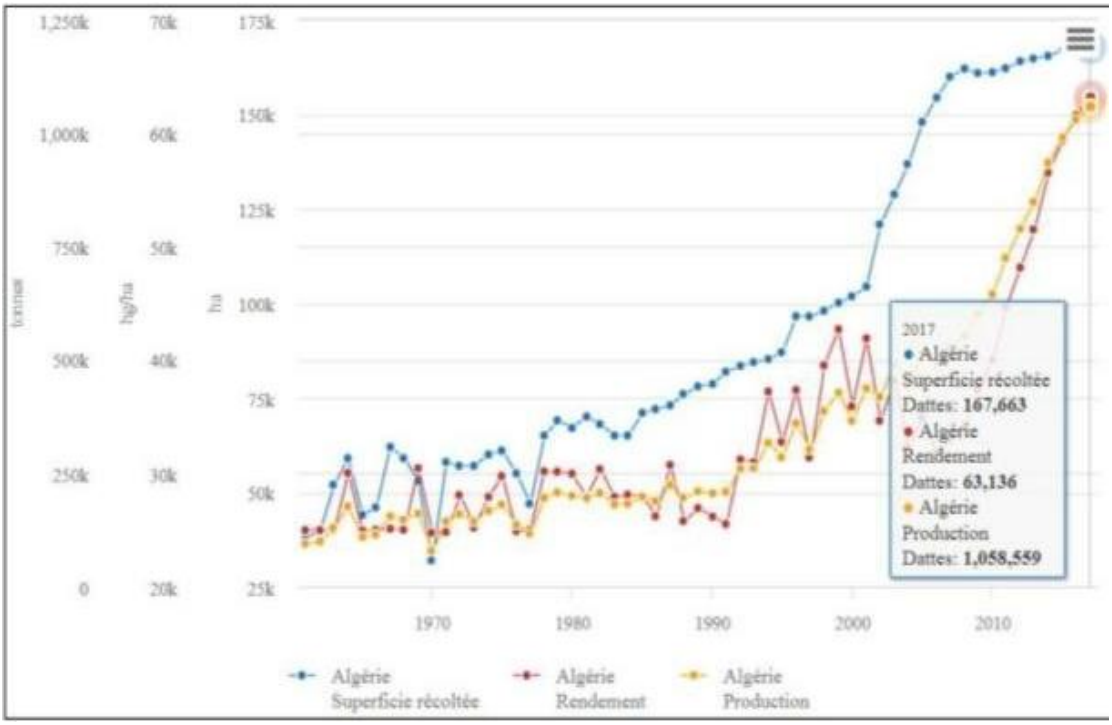


Figure 04 : National Date Production **(FAO, 2018).**

Table 02: Date Production in Algeria**(FAO, 2018).**

Province	Production (in Quintals)	Number of Palm Trees	Area (in Hectares)
Biskra	4.077.900	4.3115.100	442.910
El oued	2.474.00	3.788.500	36.680
Ouargla	١.٢٤٧٤.٠٠٠	٢.٥٧٦.٥٦٠٠	٢١.٦٨٠
Adrar	٩١٠.٣٠٠	٣.٧٩٩.٠٠٠	٢١.٩٨٠
Ghardaïa	٥٦٥.٠٠٠	١.٢٤٦.٥٠٠	١٠.٨٥٠
Bechar	٣٠٠.٥٠٠	١.٣٦.٨٠٠	١٤.١٢٠
Timimoune	١٠٩.٤٠٠	٦٨٨.٩٠٠	٧.٠٠٠
Khenchela	٦٨.٢٠٠	١٢٤.٤٠٠	٧٠٠
Tébessa	٢٠.٥٠٠	٦١.٨٠٠	٨٢٠
Laghouat	١٦.٢٠٠	٣٧.٣٠٠	٣٢٠
Illizi	١٥.٦٠٠	١٢٩.١٠٠	١٢٥٠

Batna	١٤.٠٠٠	٢٨.٧٠٠	١٩٠
El Bayadh	١٠.٣٠٠	٦٣.٩٠٠	٦٤٠
Naama	١٠.٢٠٠	٥٠.٦٠٠	٥١٠
Tindouf	٨.٤٠٠	٤٥.٢٠٠	٤٣٠
Djelfa	٦.٨٠٠	١٠.١٠٠	١٠٠
M sila	٠	٠	٠
Total	٩.٩٠٩٩.٦٠٠	١٨.٦٠٥.١٠٠	١٦٦.٩٠٠

I.3. Morphology of *Phoenix dactylifera L.*:

Date palms are perennial, monocotyledonous, dioecious plants that can be divided into three main parts

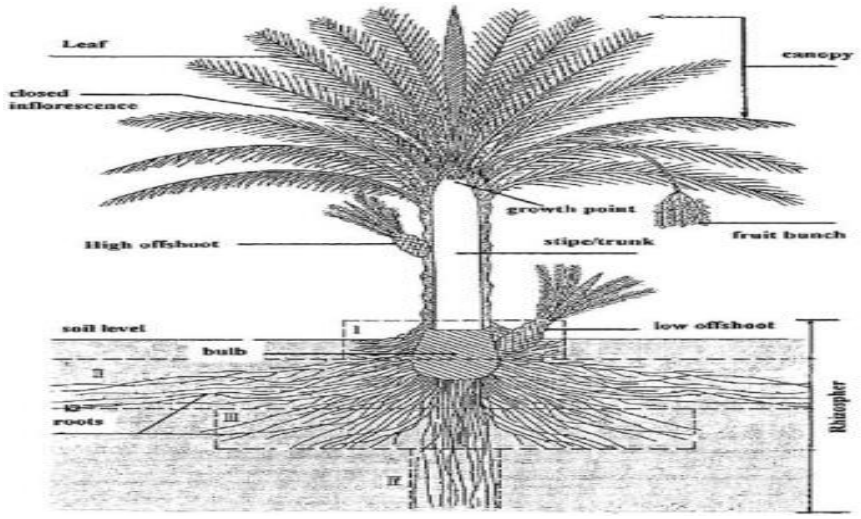


Figure05: Schematic drawing of a date palm tree**(Munier;1973)**

I.3.1.Root System of *Phoenix dactylifera*:

The root system of *Phoenix dactylifera* is characterized by broad, fibrous roots that emerge in large numbers from the peripheral zone at the base of the trunk. These give rise to secondary roots of uniform diameter, capable of growing vertically to depths of 8–10 meters and horizontally extending over 7 meters **(Elhoumaizi, 2002).** Root density in the soil decreases with depth, varying significantly depending on soil type, climatic conditions, and cultivar **(Al-Bakr, 1972).**The root system is classified into four types based on their vertical distribution: **respiratory roots** (0–20 cm), **feeding roots** (20–100 cm), **absorption roots** (100–200 cm), and **deep absorption roots** (beyond 200 cm) **(Munier, 1973; Perom, 2000).**

Date palm roots grow obliquely, providing strong anchorage for the trunk, and have a remarkable ability to produce new adventitious roots from any point along the trunk, as well as regenerate damaged or broken roots. Anatomically, date palm roots lack a cambium layer between the xylem and phloem. They also feature a network of air passages in the cortex, which connect to similar channels in the trunk and leaves, facilitating gas exchange and respiration.

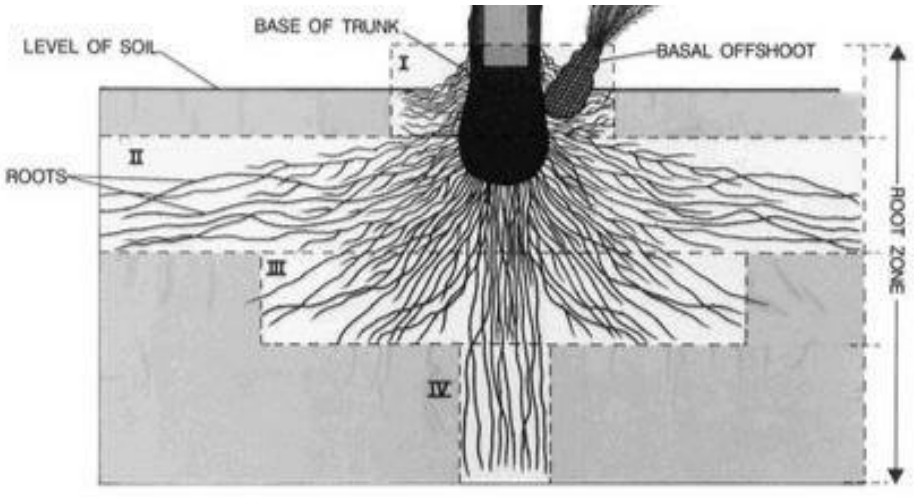


Figure 06: The root system of date palms **(Omar;2016)**

I.3.2. The Vegetative System of the *Phoenix dactylifera* Tree:

I.3.2.1. MainTrunk:

The date palm trunk features a straight, cylindrical form, typically reaching heights between 10 to 30 meters depending on the cultivar, with rare lateral branching. The trunk is covered with a fibrous layer composed of remnants from old leaf bases, serving as a protective shield against harsh weather conditions. Growth in both length and thickness occurs through the activity of temporary meristematic tissues surrounding the apical bud (growing tip), locally known as "al-jammārah." These tissues are also responsible for forming new leaves, flowers, and lateral offshoots (pups). Annual growth rates vary based on multiple factors including cultivar, environmental conditions, and agricultural practices. Mature trunks generally maintain a consistent diameter of 40 to 90 cm when proper agricultural management practices, such as periodic pruning, are implemented (**Atef & Nadheef, 1998).**

I.3.2.2. Leaves (Fronds):

Date palm leaves are long, pinnately compound fronds that emerge from the tree's growing tip. Each leaf consists of numerous leaflets arranged along a central rachis and can be anatomically divided into two main sections (**Al-Qadmani *et al*., 2013).**

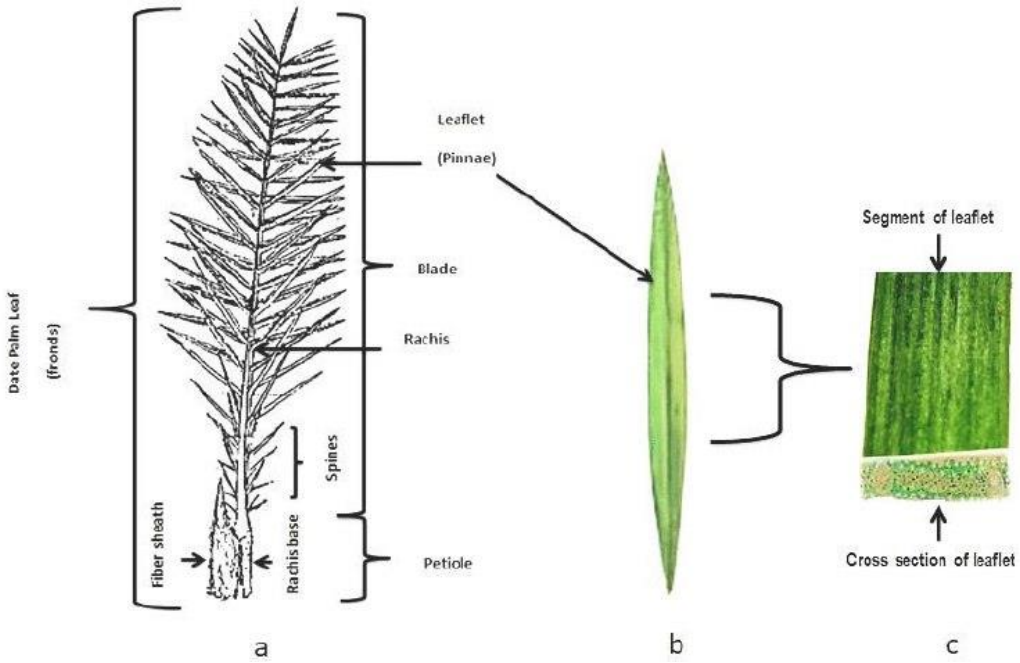


Figure 07: The morphology of date palm leaf (a) from **(Zaid and Arias-Jiménez, 2002),** (b) Pinnae (leaflet), (c) cross-section of a leaflet. Photo by authors.

I.3.2.3. Onions :

A. Leaflet Zone (Pinnae Area):

Consists of leaflets arranged alternately or oppositely along the main rachis of the frond, with their arrangement and density varying by cultivar **(Ghiyabah, 2015).** These leaflets are characterized by their flexibility and varying sizes among different varieties.

B. Spine Zone:

Located in the distal part of the frond where rigid spines replace the soft leaflets. These sharp structures serve as a defensive mechanism against overgrazing by animals.

I.3.2.4. Petiole:

The sturdy basal section of the frond that connects it to the trunk. Its fibrous composition provides structural support, particularly during stormy conditions.

I.3.2.5. Fibrous Sheath:

According to **(Atif, 1998)**this sheath consists of white parenchyma tissue interspersed with vascular bundles. As the frond matures, the soft tissue recedes, leaving behind a rough, dark brown fibrous network of vascular bundles.

This sheath:

- Enhances trunk durability and flexibility
- Provides protection against mechanical damage and animal predation
- Reduces the impact of extreme temperatures due to its insulating properties **(Al-Bakr, 1982)**

I.3.2.6. Apical Bud :

At the crown of the date palm exists a single apical bud responsible for the tree's vertical growth. This bud is protected by surrounding palm fronds and contains a fragile white tissue mass with sweet sap, locally known as "Al-Jammārah." This area is extremely sensitive, and any damage to it may halt the palm's growth or cause its death **(Atif, 1998).**

I.3.2.7. Offshoots :

Offshoots are lateral growths that emerge from specialized buds at the base of the mother palm. These offshoots develop in the palm's early years from meristematic tissues located in the leaf axils. They can be separated and cultivated as independent trees once they reach adequate size **(Atif, 1998).**

I.3.3. The Inflorescence:

The inflorescences of the date palm arise from lateral buds in the axils of its apex, between the fronds. The date palm is dioecious (unisexual) and is characterized by a very short peduncle. The flowers are borne on spikelets that cluster in the form of spikes, while the spathe (inflorescence sheath) is distinguished by a thick covering. **(Munier, 1973)**

I.3.3.1. Flowers :

A. FemaleFlowers :

The female flowers appear in a single inflorescence, ranging between **10–18 cm** in length. The shape of the inflorescence varies, with some being long and narrow while others are short and wide. The length of the floral stalks (**shamarin**) ranges between **40–150 cm(Atif, 1998).** The bracts of the female flowers are usually smaller than those of the male flowers, with a diameter of **3–4 cm**, and consist of **three carpels**, each containing a single ovule. One of the carpels is fertilized, ultimately forming a fruit. The unfertilized carpels wither and fall off, leaving traces inside the fruit's receptacle even at maturity (2003). If the fruit fails to develop, one or all three carpels may grow together, forming a single cluster. The seeds gather in one receptacle until they fully mature **(Boaghdiri, 1994).**

B. Male Flowers :

The male flowers are borne on short floral stalks (**shamarin**), measuring **15–25 cm** in length. They contain **six stamens** enclosed by a floral bract. These stamens produce pollen, which fertilizes the female flowers. The male date palm produces between 10-30 inflorescences or racemes annually **(Munir *et al*., 1999).**

I.4.3.2. Hermaphrodite Flowers and Sex Reversal :

These flowers are rarely found in seed-propagated date palms. Some inflorescences in certain male trees may bear complete hermaphrodite flowers capable of self-pollination. This phenomenon does not occur annually and is referred to as "sex reversal" **(Jibouri & Zaid, 2013:1; 2015:2).**

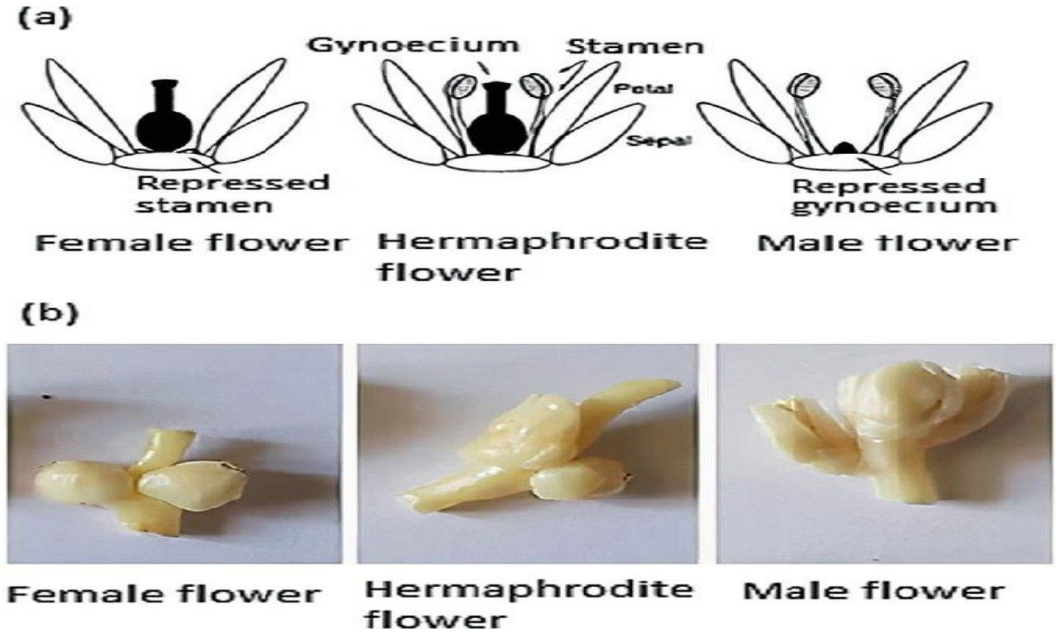


Figure 08: Male and female and hermaphrodite flowers **(Haider;2018).**

I.3.3.3. The Fruit Bunch :

The date palm begins fruit production when it reaches seven years of age. Under the weight of the fruit-bearing spikelets, the vegetative growth bends downward, forming what is called the "fruit bunch" (Al-'Urjoon) which ranges in length from 25 cm to several meters. The spikelets vary in length (10-100 cm), with each fruit bunch containing between 20-50 spikelets. Each spikelet is a slender stalk - its upper part straight and lower part zigzag-shaped - upon which the date fruits are distributed **(Jarouni,2016)**

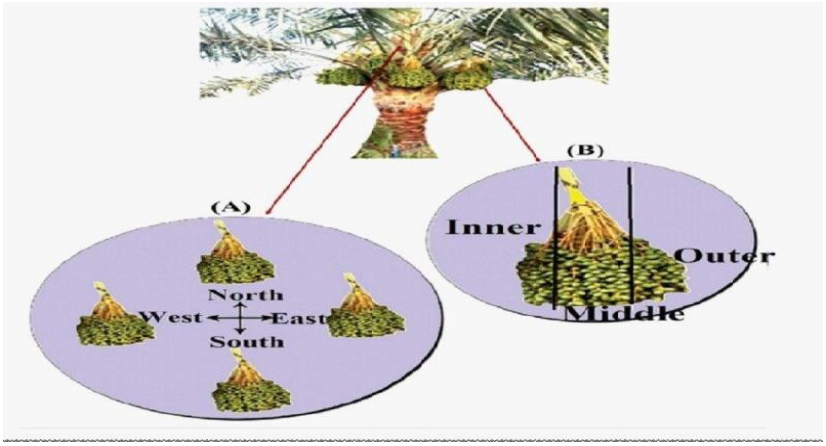


Figure 09: Date palm fruit bunches divided into (A) four directions and (B) three strand positions **(Alatawi *et al*;2023)**

I.3.4. Pollination :

The date palm is considered a **dioecious** and **monosexual** species, as its trees are distinctly divided into male trees (producing male inflorescences) and female trees (producing female inflorescences). The success of economic crop production depends on effective **pollination** (naafeeh) and successful fertilization. While natural pollination can occur via wind carrying pollen to female inflorescences, this method is economically inefficient.

Therefore, farms traditionally require equal numbers of male and female palms to optimize production resources. However, modern practices minimize the number of male trees by adopting **manual** or **mechanical pollination**.In such systems, the pollen produced by a **single male palm** is sufficient to pollinate **20–25 female palms**, depending on variables such as:

- Pollination method (varies by cultivar).
- Geographic region.
- Number of inflorescences (spathes) per male palm (10–20).
- Pollen viability and efficiency.
- Number of female inflorescences per tree (10–12 spathes).
- **Male spathes** emerge early (starting February) and when fully grown and mature, split longitudinally to reveal the stalks bearing male flowers.
- **Female spathes** appear from early March to approximately early May. **(Munier,1973)**

Figure 10: Pollination with male strands and dry pollen. (A) Separation of strands of a male inflorescence. (B) Embedding of male strands in the middle of a female inflorescence and securing with a string for its containment. (C) Pollination using a squeeze bulb. (D) Use of a cloth filled with DPP. (E) Cotton pieces embedded in the female inflorescence. (F) Common party balloons containing DPP inside. Source: Images A, B, D, E, and F (Adapted from [16,63,64]). Image C **(Photo by Ricardo Salomón-Torres 2021).**

I.3.5. Distinguishing Between Male and Female *phoenix dactylifera*:

Are dioecious plants, with distinct male and female trees. This research presents key distinguishing characteristics between the sexes according to **(Al-Fatih,2005).**

I.3.5.1. Characteristics at Seedling Stage :

Male and female date palm seedlings exhibit distinct morphological characteristics that enable early sex identification. Male seedlings typically display a rough texture with pointed, sharp-tipped leaves of a dark green coloration. In contrast, female seedlings possess softer foliage with a lighter green pigmentation **(Al-Mahmoud *et al.*, 2018)**. These observable differences facilitate preliminary gender identification before flowering onset.

I.3.5.2. GrowthRate Variations :

Mature trees demonstrate significant growth pattern disparities between genders. Male specimens exhibit slower overall growth rates with abbreviated flowering periods lasting mere weeks, directing their energy primarily toward reproductive functions. Conversely, female trees display accelerated vegetative growth but experience prolonged flowering phases extending up to six months or more. This extended reproductive commitment negatively

impacts vegetative development due to substantial resource allocation toward fruit production **(Zaid & de Wet, 2002).**

I.3.5.3. Floral Morphology and Phenology :

The flowering stage reveals notable sexual dimorphism in both timing and structural characteristics. Male trees initiate spathe emergence earlier than females under equivalent environmental conditions. Quantitative analysis shows male inflorescences are more abundant (averaging 25-35 spathes) with predominantly oval shapes and shorter lengths (15-20 cm). Female specimens produce fewer spathes (15-20) exhibiting elongated morphology with greater length (25-35 cm) and reduced width **(Elhoumaizi *et al*., 2006).**

Floral architecture further distinguishes genders - male flowers grow in dense clusters on shortened rachises (10-15 cm), while female flowers maintain wider spacing along significantly longer rachises (20-30 cm). These structural differences reflect adaptation to their respective pollination and fruit-bearing roles **(Bouguedoura *et al*., 2015).**

I.4. Environmental Requirements of *phoenix dactylifrea*:

Phoenix dactylifera cultivation is widespread in many countries around the world However, the region between latitudes 10° and 35° north of the equator, extending from the Indus River in Pakistan to the Canary Islands in the Atlantic Ocean, is considered the primary area for date farming and production. . Later, date palm cultivation spread to South Africa, Australia, the Americas, and Southern Europe, but it remains limited in these regions due to the lack of suitable environmental factors **(Awda ;2008).**

The study of climatic conditions includes the effects of temperature, humidity, rainfall, wind, light, and the relationship of each of these factors to the growth and fruiting of the date palm.

I.5.1. Temperature:

Phoenix dactylifera exhibits vegetative activity at temperatures ranging between **7-10°C**, depending on the cultivar and local climatic conditions **(Munier, 1973).** Its growth reaches maximum intensity at temperatures **above 30°C**, stabilizes, then declines when temperatures exceed **38-40°C**. Cold stress manifests at variable thresholds depending on variety, palm age, and exposure duration, with temperatures below -6°Ccausing frost damage and completedrying at -12°C **(Munier, 1973).**

Phoenix dactylifera thrive in **hot to extremely hot climates**, but fruit maturation is affected by temperature. In cooler regions, dates may fail to soften properly, remaining dry and hard . In Algeria, date palms struggle to grow below **18°C**, with optimal growth requiring **20-25°C(Anonymous, 1993).** The ideal fruit ripening temperatures are **26.6°C** for soft varieties, **32.2°C** for dry varieties, and intermediate ranges for semi-soft cultivars **(Mehaoua, 2006).**

I.5.2. Light :

Phoenix dactylifera is a plant with high light requirements, needing **intense light intensity** to achieve good fruiting. In cloudy areas with frequent overcast conditions, even when suitable temperatures are available, the palm fails to produce high-quality fruits and tends toward excessive vegetative growth and stem elongation **(Metwally and Al-Wakil, 2010; Allam, 2008).** Light directly affects the **photosynthesis process**, making the growth of palm trees abnormal in areas with weak lighting. It also plays a key role in determining fruit color, size, yield quantity, and the concentration of nutrients in the fruits (**Dawood and Ahmad, 2006).**

I.5.3. Wind:

Wind does not constitute a critical factor in *Phoenix dactylifera* cultivation compared to other fruit trees, thanks to the distinctive anatomical structure of the palm tree which features a flexible trunk and strong adhesion between the stem and leaves. However, strong winds may negatively affect productivity by uprooting tall trees and dispersing pollen grains, leading to pollination failure **(Al-Madaris, 2010).**

I.5.4. Relative Humidity and Rainfall:

Phoenix dactylifera are cultivated in areas with widely varying atmospheric humidity levels. Some regions like Egypt and Saudi Arabia record humidity rates between 27-46%, while in Iraq it ranges from 47-63%, and may exceed 75% in coastal areas. However, achieving excellent fruiting with high quality specifications requires very dry conditions with low relative humidity **(Al-Bakr;1982,Atef & Nadheef;1998).** Rainfall during the pollination season reduces the efficiency of the process and contributes to the spread of fungal diseases affecting fruits and leaves. Rainfall during the rutab stage (fruit ripening phase) is particularly harmful, as it increases susceptibility to fungal diseases and physiological disorders such as tip blackening and fruit rot **(ZAID, 2008).**

I.4.5. Soil and water factors:

I.4.5.1. Soil:

Phoenix dactylifera can be cultivated in various soil types, though they prefer light, deep soils rich in nutrients. Loamy and sandy soils are considered optimal for their growth **(Al-Bakr;1 972).***Phoenix dactylifera* exhibit high salinity tolerance compared to other fruit trees and can withstand soil acidity up to pH-8.

I.4.5.2. Irrigation Water :

Phoenix dactylifera require a permanent water source for optimal growth, contrary to previous beliefs about their drought tolerance. While exceptionally salt-tolerant (withstanding up to 6000 ppm salinity – **(Pasha, 1997),** elevated salt levels reduce yield and fruit quality.

I.5. The importance of *phoenix dactylifera* cultivation in Algeria:

Date palm cultivation (*Phoenix dactylifera L.*) holds immense ecological and socioeconomic importance in Algeria's arid regions. As the backbone of oasis ecosystems, Algeria's approximately 18.5 million date palms cultivated across 167,269 hectares produce nearly 1.03 million tons annually **(Bouguedoura, 1982).** While over 1,100 varieties exist, only a few have significant commercial value **(Rekis *et al.*, 2020**). Ecologically, date palms combat desertification through deep root systems (up to 6m) that stabilize soil **(Zaid & de Wet, 2002)** and create microclimates that reduce temperatures by 5-8°C while increasing humidity by 15-20% **(Al-Khayri *et al.*, 2015; Shabana *et al.*, 2018).** The palms support biodiversity by providing habitats for migratory birds and endangered species **(El-Juhany, 2010)**, while their byproducts are recycled as organic fertilizers and bioenergy sources.

Economically, date cultivation remains the primary income source for oasis communities, with recent development programs focusing on food security and socioeconomic improvement, despite ongoing challenges in water resource management and economic sustainability.

I.6. Main Date Varieties in Algeria:

Algeria's *Phoenix dactylifera* sector is characterized by an impressive genetic diversity, with more than 155 identified varieties **(Benamara *et al.*, 2021).** However, only a limited number of these cultivars have achieved substantial commercial significance. The most economically important varieties include Deglet Nour, Ghars, and Deglet Beida. Deglet Nour,

often referred to as the "Queen of Dates," represents Algeria's flagship variety due to its exceptional quality and accounts for the majority of the country's date exports **(FAO, 2022).** Ghars has gained prominence in both domestic and international markets for its remarkable sweetness and unique texture **(Djerbi, 2018).** Meanwhile, Deglet Beida (White Deglet) stands out as a rare, premium product distinguished by its pale coloration and delicate skin **(Bouguedoura *et al*., 2020).**

These three elite varieties constitute the foundation of Algeria's date industry and receive particular attention in export promotion strategies, as they enable the country to maintain its competitive edge in global markets **(Ministry of Agriculture, 2023).** The focused development and marketing of these cultivars support Algeria's position among the world's leading date-producing nations. The date palm (*Phoenix dactylifera*) is a strategic and iconic crop in the Algerian Sahara, representing 90% of the national territory—a vast expanse of the Sahara Desert spanning over two million km².

This cultivation plays a pivotal role in maintaining ecological balance and socioeconomic stability in these harsh environments. As a cornerstone of Saharan oases, the date palm creates a protective microclimate, enabling the growth of more delicate plant species and sustaining human settlements in otherwise inhospitable conditions. Its resilience and agricultural value make it vital for desert urbanization and oasis ecosystems **(Benamara *et al*., 2021).**

I.6.1. Deglet nour:

is the most consumed variety of date palm fruit (*Phoenix dactylifera L.*) in the Middle East and North African countries and promotes the socio-economic development of growing areas. The fruit contains a high percentage of dietary fibers, salts, vitamins, and minerals, and the dates are widely used in traditional medicine to treat various ailments**(Benzarti,S.*et al*;2025)** The soft touch, translucent light color and honey-like taste of the Algerian Deglet Nour distinguished it from other dates.

Despite being grown in several Mediterranean countries, the Deglet Nour date mainly comes from Algeria, which is still the world's largest producer of Deglet Nour dates. In Algeria, the date palm is the backbone of Saharan agriculture with a predominance of date palm about 22% of the total area of plantations, out of 11.6 million date palm, 8.8 million are Deglet Nour palms **(Kaidi and Touzi 2001).**

It is grown predominantly in the Biskra and El Oued provinces of Algeria, in the oases of Oued Righ, Tolga and M'Chouneche. The Deglet Nour dates consist of 70-80% of carbohydrates in the form of fructose, glucose and sucrose and are the most famous dates in the world (**Chouicha *et al*. 2014)**

Figure 11: a *Phoenix dactylifera* date palm along with dates. b Open fruits of Deglet Nour dates **(Chouicha *et al*. 2014)**

I.6.2. Degla beida:

Special taste White dates is a veriety that grows along water points in a single region of the country in the wilaya of Wad-sauf in Algeria.(**Ben-Salah;2021)**

Figure 12: fruits of deglet beida (**Ben-Salah;2021).**

I.6.3. The 'Ghars':

A soft date primarily produced in Ouargla, highly valued locally but unknown nationally or internationally. Lacks preservation and marketing mechanisms, with no

processing factories, limiting its distribution despite its quality. (Characteristics: Limited production - Weak marketing - Absence of processing - Local value) **(Shoukeur;2013)**

Figure 13: fruits of Ghars **(Shoukeur;2013)**

Table 03: Unique Characteristics of Algerian Dates **(Shoukeur;2013)**

Property	Deglet Nour	Ghars	Deglet Beida
Sugar Content	70-80%	75-85%	65-75%
Antioxidants	Moderate	Very High	Low
Medicinal Use	Digestive health	Immunity booster	Anemia treatment

Table 04: Comparative of Algerian Dates **(Kaidi and Touzi 2001)**

Characteristic	Ghars	Deglet Beida	Deglet Nour
Taste	Very sweet	Mild honey	Balanced
Color	Dark brown/black	Golden yellow	Light brown
Texture	Sticky soft	Semi-soft	Firm tender
Regions	Souf Valley	Biskra basin	Northern Sahara

I.7. Medicinal Benefits of *phoenix dactylifera:*

Dates offer a powerhouse of nutritional and medicinal benefits backed by scientific research. As a quick energy source, their natural sugars (fructose and glucose) provide instant fuel, making them ideal for athletes and those observing fasting periods **(Al-Shahib & Marshall, 2003).** Their high fiber content (7-8g per 100g) supports digestion and alleviates constipation. Beyond basic nutrition, dates contribute to heart health by providing potassium (656mg/100g), which helps regulate blood pressure and reduce stroke risk (USDA, 2023),

while antioxidants like phenols lower LDL cholesterol **(Baliga *et al*., 2011).** They also aid in anemia prevention due to their iron content (1.02mg/100g), which boosts hemoglobin production (**Al-Farsi *et al*., 2007).** Additionally, vitamins B6 and K in dates strengthen immune function and improve blood clotting. For specialized health needs, dates (especially the Deglet Noor variety) can be beneficial for diabetics in moderation, as their fiber and low-glycemic sugars help stabilize blood sugar (**Maqsood *et al*., 2020).** Emerging research suggests their phenolic compounds may protect brain health by reducing Alzheimer's risk and memory decline **(Subash *et al*., 2015).** Furthermore, their magnesium content (54mg/100g) supports bone strength and may reduce arthritis-related inflammation. In traditional medicine, dates have been used to treat digestive disorders (e.g., date syrup for constipation) and even sexual weakness, attributed to amino acids that may stimulate hormone production **(Subash *et al*., 2015).**

Chapter II: Chocolate

II.1. Consumption of chocolate :

Chocolate is produced through a specific manufacturing process using cocoa-derived ingredients, often combined with dairy products, sugars, sweeteners, and other additives to achieve desired flavor and texture profiles. In addition to these, other edible ingredients may be included excluding flours and starches, except in specific cases such as Le Chocolate a la taza, which may contain up to 8% wheat, corn, or rice flour/starch, and Le Chocolate familiar a la taza, with up to 18%. Non-milk animal fats can also be incorporated to develop distinct varieties of chocolate. However, the total weight of such added components must not exceed 40% of the final product's total weight **(Ziegleder *et al*., 2005)**.

Structurally, chocolate is characterized as a nearly water-free dispersion where finely ground non-fat particles such as sucrose, lactose, proteins, and minerals are distributed within a solidified fat matrix composed primarily of triglycerides. In dark chocolate, these triglycerides originate exclusively from cocoa paste, while in milk and white chocolates, they also derive from milk components **(Mohr *et al*., 1968)**.

On the consumption side, chocolate remains a globally cherished product, with notable differences in per capita intake across regions. As shown in **(Figure 15)**, Germany leads the world with an annual per capita chocolate consumption of 11 kilograms. Belgium and Switzerland follow closely at 10.9 and 10.8 kilograms, respectively. Both countries are internationally acclaimed for their high-quality chocolate production, though it is important to note that consumption statistics may be influenced by tourist purchases, as the data does not differentiate between residents and visitors **(Barel, 2015)**.

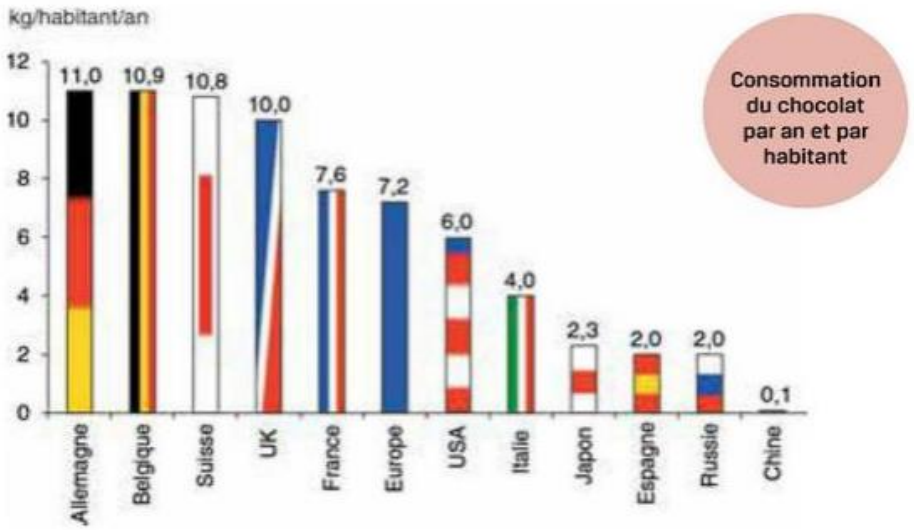


Figure 14: Global chocolate consumption per year **(Barel, 2010)**.

These statistics focus on chocolate and chocolate-related products, particularly annual cocoa consumption by country. The ranking of top-consuming nations is changing. The European Union remains the dominant consumer, accounting for 1.8 million tones or 45% of global cocoa usage. The United States follows in second place with 1.3 million tonnes (33%). Within the EU, Germany is the largest consumer (11.6%), trailed by France (10.3%), the United Kingdom (9.2%), Italy (4.6%), Spain (3.8%), Poland (2.6%), and Belgium (2.2%). Outside the EU, Russia (7.7%), Japan (6.4%), Brazil (3.7%), Canada (2.6%), and Mexico (2.5%) also contribute significantly. In contrast, China's consumption is relatively low, making up just 1.25% of the world total (**Barel, 2010)**.

II.2. Composition of chocolate:

II.2.1. Cocoa paste:

Chocolate's distinctive flavor and nutritional benefits are primarily derived from cocoa paste, a dense, brown substance produced by grinding fermented cocoa beans. This essential ingredient is packed with polyphenols (potent antioxidants), proteins, dietary fiber, healthy fats, magnesium, and natural stimulants like the obromine and caffeine, along with a range of vitamins, minerals, and trace elements that collectively support cardiovascular and cognitive health. In contrast, white chocolate contains no cocoa paste; instead, it is made from cocoa butter, sugar, and milk solids, lacking the phytochemicals and micronutrients found in dark or milk chocolate and offering primarily sweetness and fat. Despite its high nutritional value, pure cocoa paste is rarely consumed alone due to its intense bitterness, making it more

suitable as a base for chocolate products where it is blended with sugar, milk, and other ingredients to produce flavors that are more widely enjoyed **(Robert *et al*.,2014)**.

Figure 15: Cocoa paste **(Robert *et al*.,2014).**

II.2.2. Sugar:

Regulations define chocolate as containing sugar without it, it's just cocoa paste. For example, 70% dark chocolate has 30% sugar, while the rest is a mix of cocoa paste and butter (usually undisclosed). This breakdown is rarely shown on the packaging ("scarf").Originally a rare spice and medicine from sugarcane, sugar became widely consumed after its extraction from beetroot was developed by Margraff (1747), Achard (1802), and Delessert (1812),**(Robert *et al*.,2014).**

Critics often attack chocolate for being high in fat and sugar, focusing especially on sugar. Fear of sugar ("saccharophobia") isn't new it dates back to the 17th century when sugar was called a "curse." Later, Dr. Paul Carton deemed it "dead food," and Gérard Slama called anti-sugar views a "psychosocial illness." Today, some advocate regulating sugar like tobacco, backed by health campaigns (e.g., France's PNNS). Global sugar intake jumped from 5 kg/year (1850) to 25 kg (2010), largely from processed foods. While sugar is blamed for obesity and diabetes, science only confirms that excess calories not sugar alone are harmful. However, sugary drinks may contribute, as liquid calories don't satisfy hunger well, leading to overeating **(Robert *et al*., 2014)**.

Nutrition experts advise getting 45–50% of daily calories from carbs. Earlier guidelines separated complex and simple carbs (capping sugars at 10%), but this is now outdated. Instead, carbs are categorized by their glycemic index (blood sugar impact).Research shows that chocolate's chemical makeup and typical consumption amounts do not contribute to diabetes or weight gain.While sugar can trigger addictive-like responses in rats, this doesn't necessarily apply to humans. Unlike drug addiction, sugar consumption

doesn’t cause withdrawal or tolerance (needing more for the same satisfaction). Cravings are not addiction compulsive eating may stem from stress or emotional needs, not dependency. Guilt over eating sweets can also reduce pleasure, leading to overconsumption in an attempt to regain satisfaction **(Robert *et al*., 2014)**.

Most chocolate uses refined beet sugar. While some brands add whole, brown, or cane sugar for marketing claiming health benefits the nutritional difference is negligible in typical servings. Even alternative sweeteners like honey or maple syrup only slightly alter taste, not health value. Replacing sugar with fructose in 'diabetic' chocolate is also pointless and may harm heart health**(Robert et *al*., 2014).**

Figure 16: Sugar **(Paula Figoni, 2014).**

II.2.3. Sweeteners:

Because sugar is often criticized and diabetic diets limit its intake, chocolatiers have created 'sugar-free' chocolates using sweeteners instead.Since sugar makes up a large portion of chocolate (30% in 70% cocoa), intense sweeteners like stevia or aspartame can’t be used directly just 1g replaces 30g of sugar. To keep the bar at 100g, bulk sweeteners (maltitol, xylitol) are used, which have fewer calories (2.4 kcal/g vs. sugar’s 4 kcal/g). However, sugar-free chocolate often has more fat to maintain taste.Their calorie content (660 kcal/100 g) is higher than regular chocolate (572 kcal), reducing their nutritional benefits. More details are in the 'Chocolate and Diabetes' **(Robert et *al*., 2014).**

II.2.4. Soy lecithin:

Phosphatidylcholine (E 322), approved in chocolate since 1951, slightly reduces costly cocoa butter use. Mainly, it acts as an emulsifier (<1%), improving sugar-cocoa binding, enhancing viscosity, and easing flow before tempering. It also gives chocolate a shinier finish and slows whitening over time .The lecithin in the mixture usually comes from soy. However, the term "soy" worries some people due to GMO risks, making them cautious about soy lecithin in chocolate .They can rest assured GMO components in soy are found in proteins,

not lecithin (a lipid). Plus, manufacturers now guarantee non-GMO soy lecithin**(Robert et *al*., 2014).**

To prevent confusion, ease concerns, or enhance their product's appeal, some manufacturers opt for sunflower lecithin or remove lecithin entirely by adjusting conching methods. since soy lecithin is pure fat and contains no protein, it won't trigger allergies in people allergic to soy, despite common concerns.soy lecithin's impact on lipid metabolism is minimal in chocolate (only 0.3–0.5% per 100g). However, in higher doses (as a supplement), its polyunsaturated fatty acids (linoleic and alpha-linolenic) help lower total and LDL cholesterol while raising HDL cholesterol, supporting heart health .In short, there's no reason to fear or demonize soy lecithin**(Robert *et al*., 2014)**.

Figure 17: Soy lecithin **(Robert *et al*., 2014).**

II.2.5. Cocoa butter:

Cocoa butter enhances chocolate's shine and softness. Dry, rough chocolates often lack enough cocoa butter, though its exact percentage (e.g., in a 70% cocoa bar) is rarely listed. As a premium ingredient, cheaper chocolates skimp on it. Cocoa butter's price linked to cocoa bean markets can soar (e.g., $2,700/ton in 2013, with butter costing 1.98x more). Since it's odorless and flavorless, it doesn't alter taste. So, a 'Madagascar' chocolate's beans may be local, but its butter could be sourced elsewhere**(Robert *et al*.,2014)**.

High in saturated fats, but stearic acid converts to oleic acid during digestion. The final composition is roughly 27% saturated (SFA), 70% monounsaturated (MUFA), and 3% polyunsaturated (PUFA) fats **(Robert *et al*.,2014)**.

Table 05: chemical composition of cocoa butter according to Lipp (1998) **(Robert *et al.*, 2014)**.

Fatty Acid Type	Fatty Acid	Percentage (%)
Saturated fatty acids (SFA)	Stearic acid	36.48%
	Palmitic acid	25.1%
	Lauric acid	1.2%
	Myristic acid	0.2%
Monounsaturated Fatty Acids (MUFA)	Oleic acid	34.1%
Polyunsaturated Fatty Acids (PUFA)	Linoleic acid (omega-6 series)	2.8%
	Alpha-linolenic acid (omega-3 series)	0.2%

Figure 18: Cocoa butter**(Robert *et al.*, 2014).**

II.3. Types of chocolate:

We can differentiate based on the composition and proportion of the solid and continuous phases.

II.3.1. Dark chocolate:

Dark chocolate **(Figure 20)** is defined by its cocoa content, which ranges from 50% to as high as 99% the latter being exceptionally bitter. Contrary to popular belief, the quality of dark chocolate is determined not by its cocoa percentage but by the ingredients used, particularly the origin of the cocoa beans (e.g., Indonesia, Ecuador, Mexico, or Papua), which distinguishes **GRANDS CRUS(Pierre, 2007)**.

Chocolate with less than 65% cocoa has a sweet taste and is commonly labeled as "dessert chocolate" for baking. At 65–70% cocoa, the flavor becomes noticeably bitter compared to milk chocolate, making it suitable for cooking (e.g., baking chocolate) or direct

consumption. Dark chocolate with 80% cocoa has an intense, robust character, prized by connoisseurs but often perceived as too bitter or less creamy by others. Finally, varieties with 90% or more cocoa are extremely bitter and are typically enjoyed in small quantities **(Pierre, 2007)**.

Figure19: Dark chocolate**(Finley, 2014)**.

II.3.2. Milk chocolate:

Milk chocolate **(Figure21)** is a popular variation of chocolate produced by incorporating powdered or condensed milk into its composition. Unlike dark chocolate, it typically contains less than 40% cocoa solids, with U.S. regulations mandating a minimum of 10% cocoa content. In contrast**,** European standards are stricter, requiring at least 25% cocoa to be classified as milk chocolate **(Allirot, 2015)**.

Despite having a lower fat content than dark chocolate, milk chocolate is equally calorie-dense due to its higher sugar content. Historically, its mild, creamy flavor and smooth texture made it the preferred choice among consumers. However, in recent years, premium chocolatiers have begun crafting high-end milk chocolates with 45% or more cocoa, appealing to those who seek a richer taste while retaining the characteristic sweetness. One notable limitation of milk chocolate is its unsuitability for cooking, as the milk solidsit contains can scorch when exposed to high heat. This makes it ideal for directconsumption or confectionery but impractical for baked goods or sauces that require tempering **(Allirot, 2015)**.

Figure20: Milk chocolate**(Leopold, 2019)**.

II.3.3. White chocolate:

White chocolate **(Figure 22)** is made from cocoa butter combined with sugar, milk, and flavorings, but contains no cocoa solids. Due to this absence, it doesn't meet the legal definition of chocolate in many countries. U.S. regulations (since 2004) require at least 20% cocoa butter, 14% milk solids, and no more than 55% sweeteners, while EU standards specify similar minimums for cocoa butter (20%) and dairy content (14%). To achieve its characteristic shine, white chocolate requires precise tempering at lower temperatures than dark chocolate: first melted at 43°C, then cooled to 26°C, and finally reheated to 30°C before molding. Primarily used in confectionery for color contrast, its creamy texture and mild flavor make it popular despite its technical classification limitations **(Drothé, 2015)**.

Figure21: White chocolate **(Fressenel, 2018)**.

II.3.4. Couverture chocolate:

ouverture chocolate **(FIGURE 23)** is a premium-grade chocolate widely favored by professional chocolatiers and pastry chefs for its superior quality and workability. Unlike standard chocolate, couverture available in both dark and milk varieties must contain a minimum of 32% cocoa butter. This high cocoa butter content gives it an exceptionally smooth and fluid consistency when melted, allowing for a thinner, more delicate coating compared to conventional chocolates. Its luxurious texture and rich flavor make it the preferred choice for fine confections, truffles, and artisanal desserts **(Onorato, 2016)**.

FIGURE 22: ouverture chocolate **(Bazet, 2020)**.

Imitation chocolate and chocolate substitute are standardized terms defined by the **Codex Alimentarius** (1995) to describe products that mimic the sensory qualities of chocolate but fail to meet its legal compositional criteria. The primary distinction lies in their fat content: whereas genuine chocolate must contain cocoa butter as its principal fat, these alternatives replace a significant portion of it with vegetable-derived fats either lauric (e.g., palm kernel or coconut oil) or non-lauric (e.g., shea or illipe butter). As a result, such substitutes typically exhibit markedly reduced cocoa butter content, which influences not only their regulatory classification but also their melting behavior, mouthfeel, and flavor profile. These products are often developed for cost efficiency, tropical climate stability, or dietary restrictions, though they may lack the complex aroma and textural nuances of true chocolate (**Lillah *et al*., 2017; Talbot, 2011)**.

II.4. Chocolate production proces:

This section outlines the various stages of chocolate production, beginning with the harvesting of cocoa beans and concluding with the final product.

II.4.1. Obtaining the cocoa bean:

II.4.1.1. The harvest:

Commercial cocoa, often referred to simply as cocoa, is derived from beans extracted from the pods. During harvesting, the beans undergo two essential continuous processes: fermentation and drying. Once processed, they are known as cocoa beans and are typically exported in this form to consuming countries **(Mossu, 1990)**.

The growth cycle of the pods from flower pollination to fruit maturity takes approximately five to six months. As they ripen, the pods change color, transitioning from green to yellow or red to orange. Harvesting must be timed precisely to ensure optimal maturity. Harvesting should occur every 10 to 15 days, ensuring the interval does not extend beyond 3 weeks. Care must be taken during harvesting to avoid damaging the floral cushion, as it is essential for producing flowers and fruit in future cycles. Additionally, preventing injuries to the tree tissues is crucial to minimize the risk of parasitic fungal infections **(Mossu, 1990)**.

II.4.1.2. The denting:

Debossing is typically performed manually, with the optimal method involving striking the pod to split it in half along its widest point. This step breaks open the pods to release the beans, which are then prepared for fermentation **(Martin, 1970)**.

II.4.1.3. Fermentation :

This essential pre-drying operation achieves three goals:

- Removing the sticky pulp around the seeds.
- Deactivating the embryo for preservation.
- Inducing biochemical alterations in the cotyledons.

These biochemical alterations lead to the loss of the cotyledons' natural color (when present, as is typical), causing them to swell and develop a distinct brown hue **(Martin, 1970)**.

II.4.1.4. Drying :

The goal of drying is to lower the moisture content of fermented cocoa beans from around 60% to below 8%, ensuring optimal preservation during storage and transport. Two primary drying methods are used for this process **(Mossu, 1990).**

A.Natural drying:

Sun drying is the most common and straightforward method employed in many cocoa-producing nations. This process relies heavily on weather conditions and typically takes between 8 to 15 days to dry the beans completely **(Mossu, 1990)**.

B.Artificial drying:

When solar drying is impractical due to unfavorable weather conditions or when large-scale plantations necessitate extensive drying areas during peak harvest periods, artificial drying methods become essential **(Mossu, 1990)**.

C.Simple dryers:

Simple dryers consist of ovens with a cement or (preferably) slate base, where cocoa is dried by heating the surface **(Mossu, 1990).**

D.Mechanical dryers:

Large farms utilize various mechanical dryers, such as mobile rack dryers that operate in hot-air tunnels or rotary dryers where hot air flows through cocoa inside a rotating cylinder. However, these systems are only economical for processing large quantities of cocoa. The drying process typically lasts between 10 and 20 hours, depending on the cocoa's initial moisture levels **(Mossu, 1990)**.

When cocoa beans reach the chocolate factory, they are in the same state as when they were shipped from the plantations. Although they have undergone fermentation and drying, they are still unprocessed and require further refinement. Upon arrival, the beans are covered in dirt and dust from the hulling and fermentation process. The first step in processing involves preliminary cleaning, where sieves remove stones and other debris mixed in with the beans. Next, the beans are carried by a conveyor belt to storage hoppers before being transferred to cleaning and sorting machines. Here, they are meticulously inspected damaged, shriveled, or defective beans are discarded, along with any remaining impurities. Once

cleaned and sorted, the beans are either stored in containers or moved via another conveyor to the roasting ovens **(Reyes, 2012)**.

II.4.2. Obtaining cocoa paste :

II.4.2.1. Roasting:

This process is typically conducted continuously at temperatures ranging from 100 to 150°C for 20 to 40 minutes, followed by rapid cooling of the beans **(Mossu, 1990)**.

Roasting is a critical stage in cocoa processing, as it enhances the beans' flavor, aroma, and color. However, the roasting intensity must be carefully controlled excessive heat can degrade the beans' natural aroma and produce an undesirable bitterness. The optimal temperature varies depending on the bean type, with milder varieties roasted at lower temperatures and more robust-flavored beans requiring higher heat **(Reyes, 2012)**.

II.4.2.2. Crushing:

After cooling, the beans are moved to tarare crushers (also called cocoa breakers), which crack the shells and separate them from the kernels using airflow. The resulting cocoa grains kernel fragments along with the germs, are then sorted by density using vibrating screens **(Mossu, 1990)**.

A.Cocoa mixture:

The blend of beans from different origins is a carefully guarded secret unique to each chocolatier and must be finalized before grinding. The cocoa nibs undergo fine grinding at high temperatures (50–70°C) in progressively tighter roller mills. The heat liquefies the nibs into a smooth paste, and the degree of fineness directly impacts the quality of the final product, known as cocoa paste. This paste can either be kept fluid at high temperatures or molded and stored under cool conditions. Historically termed "cocoa paste," it was the first commercially processed form of cocoa. Typically produced in the country of origin, it is often exported in this state and later transformed into cocoa butter, powder, or chocolate **(Mossu, 1990)**.

B.Cocoa butter:

Cocoa butter is composed of glycerides containing oleic acid (37%), stearic acid (34%), palmitic acid (26%), and linoleic acid (2%) **(Reyes, 2012).**

The type of cocoa butter produced depends on the raw materials (such as whole beans, cocoa nibs, or cocoa paste) and the extraction method. The main categories include :

- Pressed cocoa butter (or cocoa butter): Produced by pressing the liquid cocoa paste using hydraulic presses.
- Refined cocoa butter: Obtained through pressing, extrusion (expeller), solvent extraction, or a combination of these methods, followed by refining **(Reyes, 2012).**

II.4.3. Chocolate manufacturing:

Chocolate is produced by combining sugar with two derivatives of cocoa bean processing: cocoa paste (a solid component) and cocoa butter (a fatty substance). Depending on the ratios of these ingredients and the addition of other elements like milk or nuts, various types of chocolate can be created. Chocolate is produced by combining sugar with cocoa either in the form of cocoa nibs, cocoa paste, or cocoa butter. These ingredients can be used together or individually; for instance, white chocolate consists solely of cocoa butter. Beyond these core components, other additives like stabilizers, thickeners, flavorings, or acidity regulators may be incorporated, along with milk, cream, or nuts **(Reyes, 2012)**.

Figure23: Chocolate manufacturing (Chocolate factory and chocolate industry: from bean to bar) **(Reyes, 2012)**.

II.4.3.1. Mixing:

Heated cocoa paste (maintained in a liquid state) is blended with cocoa butter and powdered sugar (sucrose). The mixture is then kneaded in a mixer until it forms a smooth, fatty liquid resulting in dark chocolate. For milk chocolate, powdered milk is incorporated during the mixing process (**Bruisma *et al*., 1999)**.

The blending process occurs in a circular kneading machine featuring a horizontal base, where heavy granite millstones rotate to mix the ingredients. This automated system ensures consistently uniform production quality. This operation ensures the mixture is homogenized and achieves the optimal consistency for grinding. At this point, the mixture has a pleasing flavor but still appears granular. The subsequent step refines the particle size to under 25 micronsaddressing this texture issue **(Afoakwa *et al*., 2008)**.

A.Grinding-refining:

The grinding and refining process reduces the particle size of the chocolate paste, which initially remains coarse (approximately 100–20 microns). This step adheres to product specifications, achieving a target fineness of under 20 microns. As the layers compact tightly and rotational speed increases, pressures reach up to 30 bars **(Afoakwa *et al*.,2007).**

The paste forms a thin film as it passes through the initial roller pair, then elongates toward the secondary rollers while traversing a precision-calibrated slit. Upon exiting the fifth roller, the chocolate achieves a thickness comparable to cigarette paper. This intensive grinding facilitates both cocoa cell fragmentation and sugar crystal pulverization. Solid particles are ground to a size smaller than 20 microns, making them undetectable by the tongue and palate. The grinding process contributes significantly to chocolate's smooth texture. Proper execution of this step is also key to achieving high-quality chocolate. The refinement stage marks the endpoint for commercial chocolate production, while quality chocolate undergoes further processing through conching **(Dukan, P.2002).**

B.Conching:

Following particle size refinement, the chocolate mass is subjected to conching a mechanical and thermal treatment that liquefies it into a homogenous, flowing state. Conching not only develops nuanced flavors but also fine-tunes viscosity and ensures a smooth melt-in-the-mouth quality **(Beckett, S.T.2009).**

The chocolate industry utilizes various types of conches, all of which function based on comparable principles: time, temperature, atmosphere, aeration, shear force, and agitation. In the past, conching was done using long machines called conches, which featured a granite tub holding the chocolate mixture and a granite roller that slid back and forth to refine the chocolate through shearing action. These devices were similar to the conching machine developed by Rudi Lindt in 1878. However, they have since been entirely superseded by

modern horizontal multi-blade rotating conches, which offer precise temperature control, improved efficiency, and eliminate issues such as sedimentation and material buildup common drawbacks of traditional long and vertical conches (Figure 25) **(Beckett, S.T.2009).**

Figure24: Conching chocolate **(Beckett, S.T.2009).**

- **Mechanical effects:**

The friction between cocoa particles wears down their sharp edges, resulting in a smaller particle size. This polishing and rounding process enhances the chocolate's plasticity, yielding a smooth, glossy, and creamy consistency. Additionally, crushed grains may release cocoa butter, further contributing to the chocolate's velvety texture **(Steinberg *et al*., 1989)**.

- **Physical effects:**

Adding cocoa butter at the final stage of conching ensures a perfectly uniform chocolate mixture. This is because the cocoa butter evenly coats every particle of the chocolate paste. Additionally, conching helps aerate and emulsify the mixture. The heat applied during the process also reduces moisture content **(Salonen *et al*., 1997)**.

- **Chemical effects:**

The decrease in astringency during conching results from the reduction of phenolic compounds and volatile components, including acids, aldehydes, esters, and pyrazines.

Sucrose is converted into glucose and fructose through a process called inversion. These transformations lead to a noticeable change in the sensory properties of the substance. Incorporating soy lecithin a natural emulsifier enhances the mixture's fluidity and stability. This produces a smooth, creamy, and soft paste with a glossy, melt-in-the-mouth texture (Fuhrman *etal*.,2001).

II.4.3.2. Tempering:

Through this sophisticated method, the chocolate achieves a shiny look, stays fresh longer, maintains a smooth consistency, and is easy to mold.In the preceding phases, the chocolate paste was continuously maintained above the melting threshold of cocoa butter. Achieving a stable solid state requires precise tempering of the chocolate **(Bruisma *et al.*, 1999)**.

This is a sensitive process since cocoa butter consists of multiple fats, each with distinct melting temperatures. If the chocolate mixture cools too gradually, certain fats may stay liquefied and break away from the main blend.This results in a hazy film forming on the chocolate's surface as it hardens. Additionally, the cocoa butter solidifies into varied crystalline structures within a temperature range of roughly 17 to 35°C. For optimal molding, however, chocolate should be tempered between 24 and 28°C, depending on the paste composition. To achieve uniform crystallization of the cocoa butter. it is crucial to prevent the formation of these mixed crystal structures **(Bruisma *et al*., 1999)**.

Additionally, it's important to note that vegetable fats derived from tropical plants permitted in chocolate at up to 5% increase the product's melting point. This enhancement improves heat resistance, offering a clear advantage for shelf stability in warmer conditions. Tempering involves slowly cooling the chocolate paste while continuously mixing it to promote even distribution of fat crystals. Afterward, the paste is gently reheated to achieve the ideal fluidity for further processing. This method follows what is known as the crystallization curve **(Dukan, P.2002; Van het Hof *et al.*, 1998).**

This cooling and heating process is performed in a tempering machine a double-jacketed tank with circulating water, fitted with a mixer and heated in a bain-marie. These machines operate automatically, using a thermostat to regulate the water temperature and precisely control the crystallization curve **(Afoakwa*et al*., 2008)**.

The chocolate paste, stored in a liquid state at 40°C, is first reheated before being transferred to the tempering machine for gradual cooling. The cooling curve varies depending on the type of chocolate: dark chocolate is cooled from 50–55°C to 26–28°C, milk chocolate from 45–50°C to 25–27°C, and white chocolate from 40°C to 24–26°C. These temperature ranges may be further adjusted depending on the chocolate's final application, such as molding or decoration. After cooling, the mass is reheated to specific temperatures for proper

crystallization: 31–33°C for dark chocolate, 28–30°C for milk chocolate, and 27–29°C for white chocolate **(Afoakwa *et al*., 2007; Hollman, 1997)**.

Tempering is not only about temperature but also time ensuring a well-temperedresult often demands a duration of 30 to 40 minutes **(**Figure26) **(Afoakwa *et al*., 2007).**

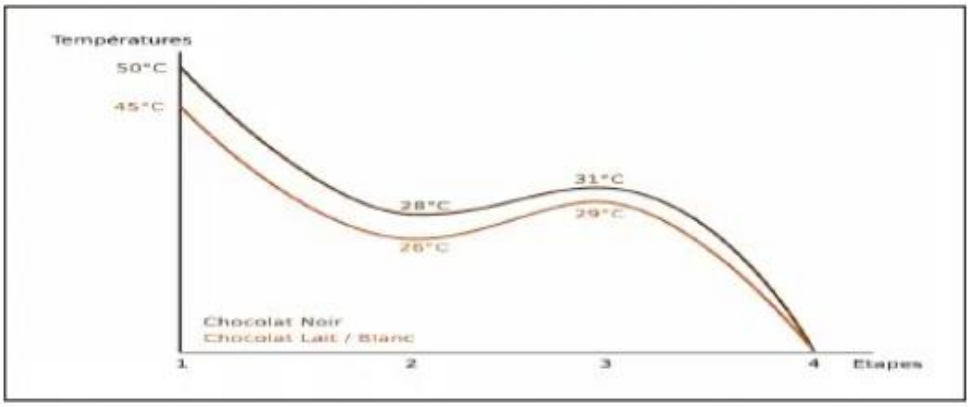


Figure25: Tempering curves for dark, milk and white chocolate**(Afoakwa *et al*., 2007)**.

II.4.3.3. Molding :

Through tempering, the chocolate paste acquired the required fluidity for molding. Following dosing, it was transferred into molds and subjected to vibrations to ensure uniform dispersion and the expulsion of air bubbles (Figure 27)**(Fuhrman*et al*.,2001).**

The chocolate paste was tempered to achieve the fluidity required for molding. Once dosed, it was transferred into molds and vibrated to ensure even distribution and the removal of air bubbles (Figure 27)**(Teissedre *et al*., 1996)**.

Figure26: Molding chocolate **(Fuhrman*etal*.,2001).**

II.4.3.4. Storage of chocolate:

The biggest threats to chocolate are excessive heat and moisture, both of which can cause unsightly blooming on its surface. To preserve its quality, store it in a cool, dry place at

10–15°C slightly warmer than refrigerator temperatures and maintain humidity levels around 60–70% **(Afoakwa *et al*.,2008)**.

Excessive heat alters the crystalline structure of cocoa butter, causing fat crystals to migrate to the surface and recrystallize, resulting in a greasy, whitish coating. While this film often called "fat bloom" does not impact the flavor of the chocolate, it significantly diminishes its visual appeal.Additionally, the high cocoa butter content makes chocolate sensitive to heat temperatures exceeding 32°C will soften it, compromise its glossy appearance, and lead to melting **(Afoakwa*et al*.,2007)**.

A humidity-induced haze is particularly troublesome. In this case, sugar crystals migrate to the surface, dissolving in the moist air before recrystallizing into an unappealing gray film. This not only compromises the chocolate's texture but also alters its taste. Additionally, chocolate readily absorbs odors from its surroundings. To preserve its quality, it should be stored in an airtight container in a well-ventilated area **(Hollman, P. C. H.1997).**

Lastly, chocolate should be stored away from light, as prolonged exposure leads to oxidation and spoilage **(Afoakwa *et al*., M.2007)**. Under proper conditions, plain chocolate bars can last for several months. However, filled chocolates have a shorter shelf life and should be eaten within one month of production. Those containing butter or cream, like truffles, are even more perishable and must be consumed within a few days **(Afoakwa *et al*.,2008)**.

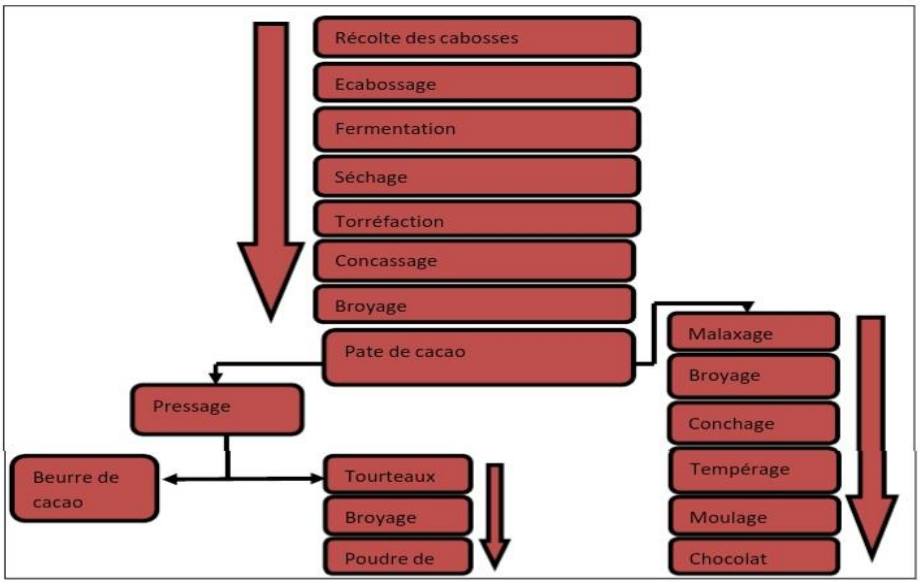


Figure27: The main stages of transformation of cocoa beans into chocolate **(Afoakwa *et al*.,2008)**.

II.5. Physicochemical and biochemical characteristics of chocolate:

This section outlines the key parameters considered in the physicochemical and biochemical analyses of various chocolate types. These tests play a crucial role in maintaining the chocolate's high quality.

II.5.1. pH of chocolate:

Chocolate typically has a mildly acidic pH, ranging from approximately 5.5 to 6.2. This pH level influences chocolate's stability and contributes to the chemical reactions involved in its production **(Beckette, 2008)**.

II.5.2. Water content:

Moisture content plays a crucial role in food preservation. Specifically, a food's water content is closely linked to its water activity, which influences the rate and intensity of chemical reactions, enzymatic processes, and microbial growth. Quality is significantly affected by relative humidity, temperature, and packaging type. Additionally, the moisture content in chocolate plays a key role in determining its storage life **(Poonam, Pandey, & Garg, 2011).**

II.5.3. Ash rate:

The total ash content in plant material refers to the inorganic residue left after complete combustion at high temperatures until a stable weight is reached. This ash reflects the mineral composition present in the food **(Campos, 2008)**.

II.5.4. Lipid content:

Lipids are a major food component, distinguished by their degree of saturation. This characteristic plays a key role in defining both the nutritional quality of foods and their oxidative stability, which affects shelf life and preservation **(Hannlie *et al*., 2006).**

II.5.5. Fatty acid composition:

The traditional method for analyzing fats and oils involves fatty acid composition analysis using gas chromatography (GC)**.** This approach identifies specific fats and oils by evaluating key parameters such as iodine value, specific gravity, refractive index, and saponification value. A major advantage of gas chromatography is its ability to detect oils that conventional methods cannot, as well as quantify the proportions of different oils within a

mixture. Additionally, this method is fast**,** versatile, and suitable for both refined and crude oils **(Ollivon & Harvé, 2003)**.

II.5.5.1. Trans fatty acids (TFA):

Research consistently shows that trans fats (TFAs) negatively impact cardiovascular health by raising atherogenic lipoproteins, LDL cholesterol, and total cholesterol, which contribute to cardiovascular disease (CVD). Due to these risks, the World Health Organization (WHO) advises limiting saturated fatty acids (SFA) and TFA intake to under 10% of daily energy requirements **(Vucic *et al*., 2015).**

II.5.5.2. Monounsaturated fatty acids:

Unlike cholesterol-promoting fats, monounsaturated fatty acids (MUFAs) do not contribute to cholesterol buildup. As a stable form of saturated fat, they resist rancidity longer than polyunsaturated fatty acids. Additionally, MUFAs have been shown to increase high-density lipoprotein (HDL) levels, supporting cardiovascular health **(Markiewicz *et al*., 2013)**.

II.5.5.3. Free fatty acids:

Chocolate producers and manufacturers closely monitor the free fatty acid content in cocoa butter, as elevated levels can compromise the quality of fermented cocoa beans and soften the butter’s texture. This acidity is primarily driven by microbial activity and the action of endogenous lipases within the beans **(Afoakwa, 2013)**.

Storage conditions including temperature, duration, relative humidity, and packaging affect free fatty acid content **(Jahurul *et al*., 2016)**.

II.5.6. Characteristics sensory :

Sensory analysis serves as a method to evaluate the organoleptic properties of a product. For chocolate production, it helps determine how key post-harvest phases such as fermentation, drying, and storage as well as subsequent processing steps influence the quality of cocoa beans and the final chocolate product **(Giorgi & Rouiquier, 2000)**.

The flavor is essentially a blend of:

- ✓ The detection of flavors by taste buds on the tongue.
- ✓ Aromas released in the mouth and sensed through retronasal olfaction at the nasal cavity's olfactory receptors.

The tongue detects four primary tastes bitter, sour, sweet, and salty each perceived most strongly in specific regions. Beyond these, umami (elicited by sodium glutamate) is another key taste **(Lefebvre & Bassereau, 2003).**

II.5.7. Nutritional aspects of chocolate:

Chocolate is a high-energy food, delivering substantial calories in small servings. It is also rich in essential minerals, vitamins, and natural stimulants. Modern chocolate is a sophisticated blend, containing over 800 different components **(Mossu, 1990).**

Table 06: The composition of a 100 g chocolate bar **(Mossu, 1990)**.

Elements	Dark chocolate	Milk chocolate
Nutrient components		
Proteins	3.2g	7.6g
Lipids	33.5g	32.3g
Carbohydrate	60.3g	53.0g
Pure lecithin	0.3g	0.3g
Alkaloids (especially theobromine)	0.6g	0.2g
Minerals		
Calcium	20mg	220mg
Magnesium	80mg	50mg
Phosphate	130mg	210mg
Trace Elements		
Iron	2.0mg	0.8mg
Copper	0.7mg	0.4mg
Vitamins		
A	40U.I.	300U.I.
B1	0.06mg	0.1mg
B2	0.06mg	0.3mg
C	1.14	70U.I.
D	50U.I	70U.I.
E	2.4mg	1.2mg
Absorbable energy		
Calories	495	515

II.6.7.1. Macronutrients:

A.Carbohydrates:

The carbohydrate content in chocolate depends on its cocoa percentage higher cocoa means less sugar. For example, chocolate with 53% cocoa contains 47% added sugar, whereas a 70% cocoa version has only 30%. These carbohydrates come from both the cocoa bean [including simple sugars (sucrose, fructose, glucose) and polysaccharides (starch, cellulose, pectin)] and added sweeteners (like sucrose and glucose syrup) during processing **(Daverio, 2005)**.

Dark chocolate typically contains finely ground crystallized sucrose. However, regulations allow the use of alternative sugars instead of sucrose. Chocolate products may include up to 5% of their total weight in crystallized glucose (dextrose), fructose, lactose, or maltose either individually or combined without requiring explicit declaration on the label. If crystallized glucose (dextrose) makes up more than 5% but no more than 20% of the product's total weight, the name of the product must include the label "with crystallized glucose" or "with dextrose**(Daverio, 2005)**.

Filled" chocolates such as those containing hazelnuts or dried fruit tend to have higher amounts of non-digestible cellulose and starch. On average, dark chocolate contains 63g of carbohydrates per 100g, accounting for 60% of its total calorie content. Even when sucrose is substituted with polyols* (like sorbitol) or other sweeteners, the nutritional value of chocolate decreases by just over 15% **(Daverio, 2005)**.

B.Lipids:

Lipids derived from cocoa butter contribute 30% of the caloric content in dark chocolate. These lipids consist mainly of fattyacids in triglyceride form, with the following composition:

- ✓ 60% saturated fatty acids (palmitic acid: 26%, stearic acid: 34%).
- ✓ 40% unsaturated fatty acids (oleic acid: 37%, linoleic acid: 2%, and arachidonic acid: Cl%).

Stearic acid is rapidly desaturated in the body, converting to oleic acid and effectively raising the oleic acid content to nearly 70%. Overall, the saturated fatty acid portion can be estimated at approximately 25%, while unsaturated fatty acids make up about 75%. Sterols and small amounts of vitamin D are present alongside fatty acids, which play a crucial role in

transporting fat-soluble vitamins (A, D, E, and K). The stability of cocoa butter is maintained by tocopherol (vitamin E), which prevents oxidation. Additionally, cocoa butter contains minimal cholesterol averaging just 1.3 mg per 100 g making it almost negligible **(Daverio, 2005).**

C.Proteins:

There are 5 grams of protein in every 100 grams of dark chocolate.

Dark chocolate is a nutritionally complete protein source, containing all eight essential amino acids that the body must obtain from food isoleucine, leucine, lysine, phenylalanine, methionine, threonine, tryptophan, and valine. However, their concentrations are lower than those in eggs, which are considered the gold standard for amino acid balance. Unlike milk or white chocolate, dark chocolate lacks dairy, resulting in roughly half the protein content. Despite this, its proteins still support critical bodily functions, including growth, tissue maintenance, and repair **(Daverio, 2005)**.

II.5.7.2. Micronutrients:

A.Minerals:

Chocolate is rich in essential minerals that contribute to both physical health and cognitive function. Chocolate is rich in magnesium, which contributes to its antidepressant effects partly due to endorphins. But beyond that, it's also a valuable source of essential trace minerals. According to the table, a 100-gram serving of 70% cocoa chocolate provides 20–50% of an adult's daily recommended intake of magnesium, phosphorus, potassium, copper, and iron a significant contribution. Additionally, it contains fluoride, which aids in cavity prevention **(Daverio, 2005).**

Table 07: Composition du chocolat en minéraux et oligo-éléments **(Barel, 2010)**.

According to European Directive No. 90/496/EEC of May 2003	Daily needs of adults	Contribution due to 100 g of dark chocolate (70% cocoa)	
	In quantity	In quantity	As a percentage of daily requirement
Magnesium	375mg	180mg	48%
Phosphorus	700mg	300mg	42%

Potassium	2000mg	500mg	25%
Copper	1.3mg	0.32mg	25%
Iron	14mg	3mg	21%
Calcium	1000mg	60mg	6.0%
Iode	120ug	5ug	4.2%
Fluorine	2000ug	50ug	2.5%
Sodium	600mg	11mg	2.0%
Nickel	15mg	0.2mg	1.3%

B.Vitamins:

Chocolate contains a significant amount of vitamins, which are crucial molecules for maintaining metabolic balance. Partial or complete deficiencies in these vitamins can result in severe health complications **(Daverio, 2005)**.

A 100-gram serving of chocolate covers at most 18% of the recommended daily vitamin E intake, whereas most other foods provide close to or below 10%. Thus, vitamins are best obtained from sources such as fruits, vegetables, meat, and fish rather than chocolate **(Daverio, 2005)**.

Table 08: Vitamins in chocolate **(Barel, 2010)**.

	Daily needs of adults	**Contribution due to 100 g of dark chocolate (70% cocoa)**	
	in quantity	in quantity	in % of daily requirement
Vitamin E (tocopherol)	15ug	2.7ug	18%
Vitamin D (calciferol)	10ug	1.36ug	14%
Vitamin B5 (pantothenic acid)	8mg	0.6mg	7.5%
Vitamin B1 (thiamine)	1.4mg	0.07mg	5%
Vitamin B2 (riboflavin)	1.6mg	0.08mg	5%
Vitamin PP (vitamin B3, niacin)	17mg	0.86mg	5%
Vitamin B6 (pyridoxine)	2.1mg	0.02mg	1%
Vitamin A (retinol)	5.4mg	0.02mg	0.4%

Vitamin B9 (folic acid)	400ug	0.01ug	
Vitamin C (ascorbic acid)	80ug	-	
Biotin	200ug	-	
Vitamin B12 (cobalamin)	3ug	-	

II.6. Quality control in chocolate production:

Maintaining strict quality control in chocolate production is essential to guarantee that the final products adhere to both quality and safety requirements. Below are some of the most widelyrecognized standards inthechocolate industry used to uphold effective quality assurance:

1. ISO 9001: is a globally recognized standard that sets the framework for a robust quality management system (QMS). In chocolate production, it provides guidelines for establishing processes that ensure product consistency, efficiency, and adherence to regulatory standards.

2. ISO 22000: outlines the criteria for a food safety management system. It is applicable for guaranteeing the safety of chocolate products across all stages of production, from raw material intake to the distribution of the final goods.

3. HACCP (Hazard Analysis Critical Control Point): is a structured approach used to identify, evaluate, and manage food safety hazards. In chocolate production, implementing HACCP is crucial to mitigate contamination risks and guarantee the safety of consumers.

4. Good Manufacturing Practice (GMP): GMP refers to the fundamental standards that guarantee the quality and safety of food products. These practices cover key areas such as personal hygiene, facility conditions, sanitation, equipment maintenance, and other critical aspects of chocolate production.

5. Industry-Specific Standards: The chocolate industry adheres to specialized regulations, including standards set by the International Cocoa Organization (ICCO) and other trade associations. These guidelines often focus on key aspects of production, such as minimum cocoa content, allowable additives, and quality control measures **(Enoh, 2013).**

II.7. Avantage and inconvenient of the consumption of chocolat:

Just as chocolate has many positives, it also comes with some drawbacks that cannot be ignored**.** It is a favorite treat among people of all ages due to its unique taste and ability to

boost mood. However, excessive consumption may lead to health problems such as weight gain or increased blood sugar levels. Therefore, it is important to consume it in moderation and enjoy its benefits without harming one's health.

II.7.1. Avantage of chocolat consumption:

II.7.1.1. Protection against vascular endothelial disorders:

Previous research indicates that regular intake of dark chocolate can reduce the risk of high blood pressure, thereby delaying the onset of cardiovascular diseases **(Grassi *et al*., 2005b, 2008)**. A major contributor to atherosclerosis is vascular endothelial dysfunction, primarily caused by decreased nitric oxide (NO) bioactivity, leading to impaired flow-mediated vasodilation (FMD). Cocoa flavonols help boost circulating NO levels, enhancing FMD response in conduit arteries and significantly improving microcirculation. Notably, epicatechin-7-O-glucuronide has been identified as a key predictor of these vascular benefits following the consumption of flavonol-rich cocoa **(Schroeter *et al*., 2006)**. Additionally, cocoa flavonols enhance vascular endothelial function by improving platelet activity, particularly in healthy smokers, within 2–8 hours of ingestion **(Engler *et al*., 2004; Wang-Polagruto *et al*., 2006; Nogueira *et al*., 2012)**.

II.7.1.2. Protection from diabetes:

Dark chocolate enhances insulin sensitivity by mitigating insulin resistance and maintaining vascular health, thereby promoting unimpaired blood flow. Impaired insulin production can arise from reduced nitric oxide (NO) synthesis by the NOS enzyme, contributing to insulin resistance. The epicatechin in cocoa boosts endogenous NO production, which activates PI3K signaling a pathway critical for insulin-mediated glucose transport in metabolic tissues, upregulating Akt activation. Insulin’s hemodynamic effects include capillary recruitment, which further enhances glucose uptake **(Grassi, 2005a)**.

Additionally, cocoa polyphenols employ a dual mechanism (via Akt/PI3K and ERK1/2 pathways) to stimulate insulin secretion from pancreatic β-cells. Procyanidin, another bioactive compound in dark chocolate, lowers postprandial blood glucose levels. Despite its low bioavailability, procyanidin interacts with glucose transporters, facilitating GLUT4 translocation to muscles. This process improves systemic glucose clearance and strengthens insulin signaling **(Kerimi & Williamson, 2015; Grassi *et al*., 2005b)**.

II.7.1.3. Protection from oxidative stress:

Dark chocolate has garnered scientific interest due to its potent antioxidant properties and potential role in cancer risk reduction **(Wan *et al*., 2001)**. Metabolic processes constantly produce free radicals, which can damage healthy cells; however, dark chocolate consumption has been shown to mitigate this cellular damage **(Baba *et al*., 2000)**. The antioxidants in dark chocolate neutralize free radicals, helping protect the body from premature aging and cancer development **(Davison *et al*., 2012)**.

Additionally, dark chocolate boosts mitochondrial activity, as evidenced by increased citrate synthase activity, and elevates glutathione levels, offering defense against oxidative stress. The epicatechin found in dark chocolate enhances mitochondrial biogenesis by raising nitric oxide levels, which activates the co-activator PCG-1α a key regulator of mitochondrial production. These effects improve mitochondrial function, shield cells from oxidative stress, and enhance overall cellular metabolism. Furthermore, better mitochondrial function increases ATP production, supporting skeletal muscle performance. Epicatechin also plays a protective role in mitochondria by directly inhibiting the mitochondrial permeability transition pore (mPTP), thereby preventing cell death **(Pinilla *et al*., 2015; Decroix *et al*., 2017; Munoz *et al*., 2013)**.

II.7.1.4. Weight gain:

Dark chocolate is also beneficial for weight management due to its relatively low-calorie content. Regular consumption has been linked to a reduction in obesity. Cocoa polyphenols interfere with the early stages of fat cell formation (adipogenesis) in preadipocytes. **IN VITRO** studies suggest that cocoa polyphenol extract can suppress diet-induced adipogenesis by inhibiting mitotic clonal expansion a crucial step in DNA remodeling that regulates gene expression during fat cell development **(Farhat *et al*., 2014)**.

Additionally, cocoa polyphenols block two key transcription factors peroxisome proliferator-activated receptor gamma (PPARγ) and CCAAT enhancer-binding protein alpha (C/EBPα)leading to reduced mRNA expression of fatty acid synthase in these cells **(Farhat *et al*., 2014; Kord-Varkaneh *et al*., 2019)**.

II.7.1.5. Maintenance of healthy lipid profile:

Consuming dark chocolate in moderation helps maintain healthier blood cholesterol levels. Cocoa compounds inhibit cholesterol absorption and synthesis by reducing the

availability of cholesterol receptors. These cocoa products effectively lower LDL ("bad" cholesterol) and total cholesterol levels while maintaining stable HDL ("good" cholesterol) levels. Additionally, cocoa polyphenols decrease lipid peroxidation in both liver tissue and bloodstream, resulting in reduced malondialdehyde production. Notably, cocoa fiber intake does not significantly affect liver glutathione levels **(Lecumberri *et al.*, 2007)**.

II.7.1.6. Stimulate brain function:

Cocoa is thought to have energizing effects on the body, which is why cocoa-based products are often consumed before strenuous activities **(Toplar, 2017)**. Additionally, dark chocolate plays a key role in improving brain function. Research suggests that dark chocolate (DC) enhances blood circulation in both the heart and the brain. The bioactive compounds in dark chocolate have been shown to boost cognitive performance and help regulate mood **(Lippi *et al.*, 2009)**. Furthermore, dark chocolate has a beneficial impact on nerve growth factors and increases plasma theobromine levels **(Sumiyoshi *et al.*, 2019)**.

II.7.1.7. Anti-inflammatory effect:

Research has demonstrated that dark chocolate possesses anti-inflammatory properties. It upregulates mRNA expression, particularly that of the anti-inflammatory cytokine IL-10, while reducing pro-inflammatory stress responses. Additionally, cocoa exerts direct effects on immune cells, enabling it to modulate both innate and adaptive immunity. Studies indicate that cocoa consumption helps regulate the secretion of inflammatory mediators by macrophages and other leukocytes **(Dugo *et al.*, 2017)**. A summary of dark chocolate's health benefits is presented in **(Figure29)**.

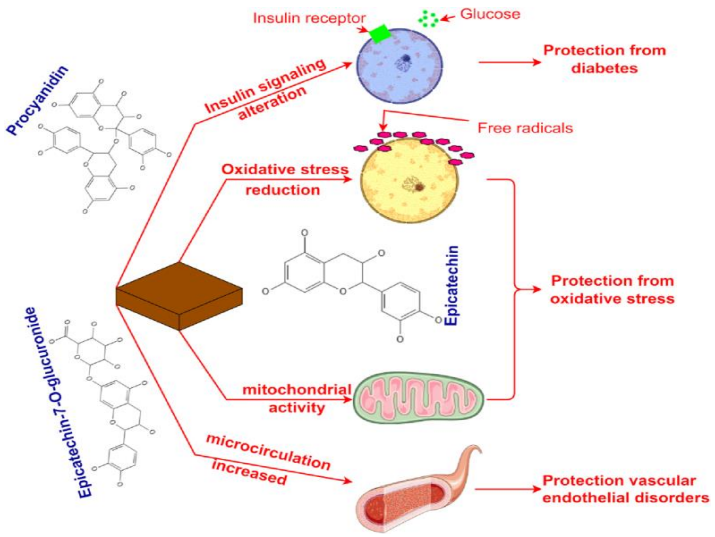


Figure28: Health benefits of dark chocolate**(Dugo *et al.*, 2017)**.

The health benefits of dark chocolate are intrinsically linked to the complex composition of cocoa beans. These beans are rich in cocoa butter, proteins, and methylxanthines such as caffeine and theobromine, in addition to essential minerals like zinc, phosphorus, potassium, iron, copper, and magnesium. Notably, cocoa is also a potent source of antioxidants particularly catechins, dietary polyphenols, proanthocyanidins, and anthocyanidins which contribute significantly to its protective effects on human health.

Like many plant-derived foods, cocoa contains a substantial amount of polyphenols, natural compounds known for their strong antioxidant properties. These compounds help neutralize free radicals (reactive oxygen species) generated through stress, exercise, and metabolic activities, which can accelerate cellular aging and contribute to the development of certain cancers. Among polyphenol-rich foods, dark chocolate is particularly notable. The concentration of polyphenols varies by cocoa-based product: commercial cocoa beans contain approximately 5%, cocoa powder around 2%, dark chocolate about 0.8%, and milk chocolate roughly 0.5%.

Polyphenols in cocoa are divided into several biochemical categories, with anthocyanins and flavanols being the most abundant in commercial cocoa. These two groups are primarily responsible for the antioxidant activity of cocoa. Additionally, cocoa contains small amounts of rare hydroxycinnamic derivatives (HCDs), which may also contribute to its bioactivity. The first two anthocyanins and flavanols are primarily responsible for cocoa's antioxidant properties (**Barel, 2010**). The overall nutritional value of cocoa is high, providing approximately 836.8 kJ (200 kcal) per 100 grams, with a detailed composition outlined in **(Table 11)**.

Table 09: Nutrient composition of Cocoa bean (100 g).

Name of the Nutrients	**(Abt *et al*., 2020)**	**Caprioli *et al*. (2016)**	**Aremu *et al*. (1995)**	**Afoakwa *et al*. (2013)**	**Poveda *et al*. (2020)**
Energy (Kcal)	536	504.6	-	-	122
Moisture	-	3.53	5.0	4.2	3.60
Fiber (g)	-	-	5.9	-	3.60 - 13.13
Protein (g)	10.71	12.16	15.5	21.6	10.30 - 27.40
Carbohydrates (g)	-	34.53	-	-	7.85 - 70.25

Fat(g)	53.57	35.34	-	55.2	1.50-49
Saturated	32.14	-	-	-	-
Sodium (g)	-	-	-	3.4	16.00-192.20
Calcium (mg)	-	-	29.2	140.2	0.23-0.44
Potassium (g)	-	-	-	2313.1	1.25-1.82
Iron (mg)	2.57	-	-	2.7	27.62-80.50
Phosphorus (mg)	-	-	201.0	236.6	58-100
Copper (mg)	-	-	-	11.1	2.53-6.62
Zinc (mg)	-	-	-	9.7	2.75-19.00
Magnesium (mg)	-	-	-	286.8	48-192

II.7.2. Inconvenient of chocolat the consumption:

Today, while chocolate is praised for its potential health benefits, it is equally important to acknowledge the possible negative effects associated with its consumption. As interest in chocolate's role in human health grows, so does the need for a balanced understanding that includes its drawbacks. Scientific studies have shown that certain types of chocolate particularly those high in added sugars, fats, and calories may contribute to health problems when consumed excessively. Therefore, just as chocolate can support well-being, it can also pose risks, especially when moderation is not observed.

II.7.2.1 Diabetes:

The sucrose in chocolate is quickly broken down by the body, leading to a rise in blood sugar levels. For this reason, chocolate is generally not advised for people with diabetes. However, the risks are significantly lower with dark chocolate containing at least 70% cocoa, and the impact may also vary depending on the type of diabetes. To stay on the safe side, diabetics with a sweet tooth should always consult their doctor before indulging **(Barel, 2010)**.

II.7.2.2. Hypercholesterolemia:

Elevated total cholesterol, high LDL ("bad" cholesterol), and low HDL ("good" cholesterol) are among the top diet-related risk factors for cardiovascular disease**.** When you consider it, serum cholesterol testing is fascinating we can analyze blood components, assign numerical values, and even predict future health risks before symptoms appear. Once we have

these results, the goal is to use them as motivation to improve through diet and lifestyle changes. If that's not a glimpse into the future of preventive medicine, what is? **(Ploeg & Ruscigno, 2014)**.

Contrary to common assumptions, dark chocolate does not negatively impact cholesterol. For one, its cholesterol content is minimal averaging just 1.3 mg per 100 grams, which is practically insignificant. Beyond that, studies suggest it has a neutral effect on cholesterol levels. This is largely due to its cocoa butter, which contains a balanced mix of unsaturated and saturated fatty acids.Thus, dark chocolate seems to positively influence the lipid profile in healthy individuals, helping prevent atherosclerosis. As a result, it can be enjoyed in moderation without worry, even by those with high cholesterol. However, not all experts confirm this hypothesis **(Daverio, 2005)**.

With 18.2 mg of cholesterol per 100 g (from its milk content), milk chocolate does not pose a significant risk for high cholesterol and cannot be considered hypercholesterolemic **(Daverio, 2005)**.

II.7.2.3. Obesity:

Chocolate is high in fats and carbohydrates, making it an energy-dense food. While fats are often linked to weight gain, carbohydrates are converted into glucose upon digestion, prompting the pancreas to release insulin. This hormone helps regulate blood sugar but also promotes fat storage by trapping fatty acids as reserve energy, which the body uses during physical activity. That said, chocolate itself doesn't cause weight gain when consumed in moderation as part of a balanced diet. Since it's not a dietary staple, it can be enjoyed occasionally. For healthier choices, opt for low-sugar varieties and pay attention to accompanying foods. Be mindful, however, as chocolate is commonly found in processed snacks, which are more likely to contribute to excess weight.

Nutritionists agree that overly restrictive diets should not exclude enjoyable foods entirely. In fact, incorporating moderate amounts of chocolate into a low-calorie diet can help prevent intense cravings (**Daverio, 2005)**.

II.7.2.4. Constipation:

Despite its high fiber content (at least 10%), which aids digestion, chocolate is often blamed for causing constipation. Some suggest that its tannins (polyphenols) may counteract this benefit by slowing intestinal movement. However, epidemiological research indicates that

these opposing effects balance each other out, meaning chocolate has no significant impact on constipation **(Barel, 2010).**

II.7.2.5. Nutritional and energy value:

Chocolate serves as an ideal energy source for athletes, offering a high caloric density that helps sustain endurance during prolonged physical exertion.

One of chocolate's key traits is its ability to provide energy. Thanks to its blend of sugars and fats, it delivers a high caloric value in a compact form. For instance, 100 grams of dark chocolate (with at least 50% cocoa) roughly one bar contains 560 kcal (2,340 kJ). Milk chocolate offers nearly the same, at 550 kcal (2,300 kJ) per 100 grams. In comparison, the same amount of bread provides only 250 kcal (1,050 kJ). Considering the average person requires about 2,400 kcal (10,000 kJ) daily, chocolate becomes a valuable energy source, especially for athletes who need sustained fuel for endurance activities. Notably, dark chocolate is not classified as a fast-acting sugar, supported by its low glycemic index of 22 **(Barel, 2010)**.

Thus, chocolate is a nutritionally complete food, highly energetic because of its abundant carbohydrates, lipids, and proteins.

Additionally, chocolate serves as a source of essential mineral salts. Its significant magnesium and iron content can help address dietary deficiencies in these elements when needed. Furthermore, chocolate contributes a considerable amount of phosphorus **(Mossu, 1990).**

Conventional sugar is considered a contributing factor to the increased risk of chronic diseases such as diabetes and obesity, due to its negative impact on blood sugar levels and its lack of essential nutrients. Based on these concerns, the search for safer, natural alternatives has gained importance. Date sugar has emerged as a promising healthy option, as it contains natural sugars along with vitamins and minerals that support overall health and help reduce the harmful effects associated with refined sugar consumption.

Second part:

Experimental part

Chapter III:Materials and methods

III. Materials and methods:

This study aims to explore the potential use of sugar extracted from local date varieties Ghares, Deglet Nour, and Degla as a natural substitute for refined sugar in chocolate production**.** These date samples were collected from the Djamaâ area of El M'Ghair province, southeastern Algeria. The research focused on evaluating the physico-chemical and sensory properties of chocolate produced with this alternative sugar. This approach aims to promote healthy, locally sourced ingredients, aligning with global trends toward sustainability and reduced use of refined sugar.

III.1. Representation of the study area:

Djamaâ (**Figure31)** is bordered by the municipality of Tendla to the north, Sidi Amrane to the south, Reguiba to the east, and El M'Rara to the west. It spans an area of approximately 780 km² (78,000 hectares). According to 2008 statistics, the population was 50,373 inhabitants, with a density of 64.58 inhabitants/km². This number increased to 68,495 inhabitants in 2017, with a density of 70.09 inhabitants/km², concentrated primarily in the main population centers. Climatically, Djamaâ falls within a dry Saharan zone characterized by long, extremely hot summers and mild winters. The area experiences low and irregular rainfall and high annual evaporation rates, which negatively affect water resources and agriculture, especially without modern irrigation or conservation techniques. Maximum summer temperatures range between 40°C and 47°C, while winter highs range between 18°C and 25°C. Minimum temperatures can drop to 5–10°C in January and exceed 30°C at the peak of summer. Average annual rainfall is generally low, rarely surpassing 100 mm **(TAHIRO,2018)**.

Administratively, Djamaâ has significant development. It was initially part of Biskra Province and included three secondary settlements: Tegdidine, Mazer El Zawia, and Old Djamaâ. In 1984, it became the seat of a district under El Oued Province, with the addition of Sidi Yahia as a secondary settlement. As part of the recent administrative restructuring, Djamaâ officially became part of El M'Ghair Province **(Figure30)** , in line with national efforts to decentralize governance and improve local development in interior regions **(TAHIRO,2018)**.

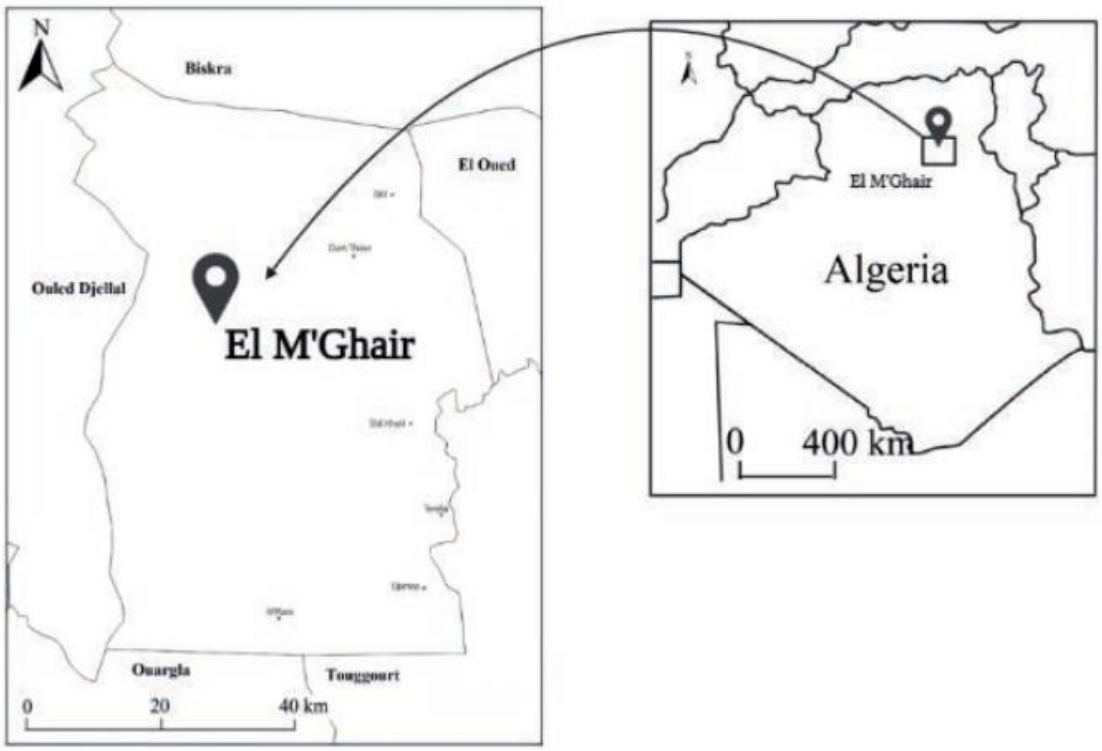


Figure 29: Geographical map of the Wilayat of Al-Mughair**(BENAMOR *et al.*, 2024).**

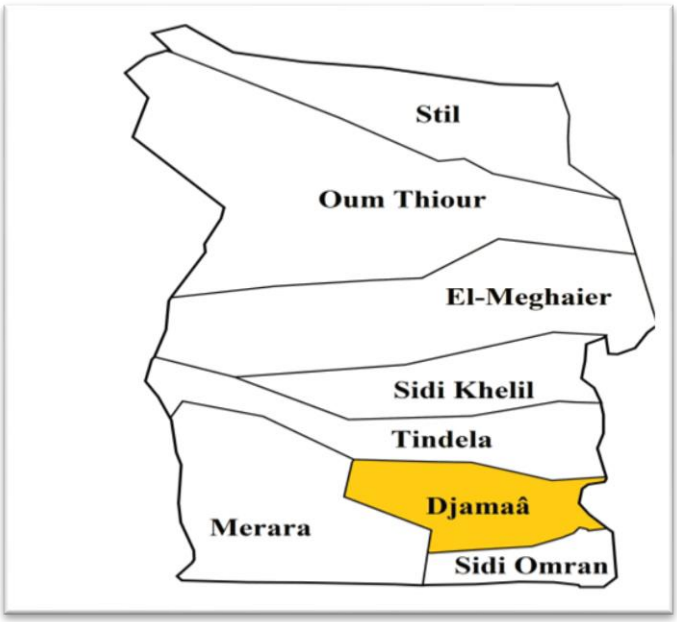


Figure30: Map of the study area (Djamaâ municipality of El Meghair province in this study) **(TAHIRO,2018)**.

III.2. Preparation of the Sample:

The Djamaâ region (El M'Ghair Province, Algeria) was selected as a primary station for date palm sample collection due to its unique geomorphological and climatic characteristics. The area is located within a low-lying sedimentary basin on the western edge of the Grand Erg Oriental, with sand dunes covering approximately 35% of the total study area. The landscape features a variety of landforms, including wide plains, sebkhas, and some dynamic sandy formations. The soil is of silty origin from the Quaternary period, renewed by wind action, predominantly sandy in texture, and exhibits medium to high salinity levels **(TAHIRO,2018).**

Samples were collected during the autumn season, specifically in October 2024, to ensure optimal ripeness and accurate representation of the physico-chemical properties of each variety. The exact geographic coordinates of the collection site are:Al-Zawalia : 33°32'1.97" N, Longitude 5°59'35.02" E. The selected cultivars included: Degla Baida, Ghars, and Deglet Nour, all belonging to the species Phoenix dactylifera L. These varieties were chosen for their local significance and high sugar value. The primary goal of the sampling process was to extract natural sugars, especially sucrose, to explore their potential use as a natural sweetener for chocolate production **(TAHIRO,2018)**.

Figure 3١: Degla Bayda.**(Benchaoui S ; Hamidi A:2025)**

Figure32: Deglet Nour. **(Benchaoui S ; Hamidi A :2025)**

Figure33: Ghars. **(Benchaoui S ; Hamidi A :2025)**

III.3. Extraction of the Water-soluble sugar:

1.Step 01: Preparation of date juice:

1.We wash the three varieties of dates with distilled water in order to eliminate solid impurities of sand and clay stones.

2. The dates were cut into small pieces, and a precise amount of 250 grams was weighed for the sugar extraction process.

Figure 34: Weight of dates. **(Benchaoui S ; Hamidi A :2025)**

3. 250 g of dates were mixed with 300 ml of distilled water, and then the mixture was heated at 50°C for 1 hour.

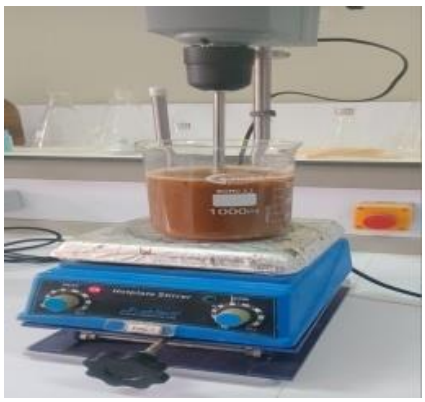


Figure 35: Preparing date juice.**(Benchaoui S ; Hamidi A:2025)**

Figure36: date juice (Ghars). **(Benchaoui S ; Hamidi A:2025)**

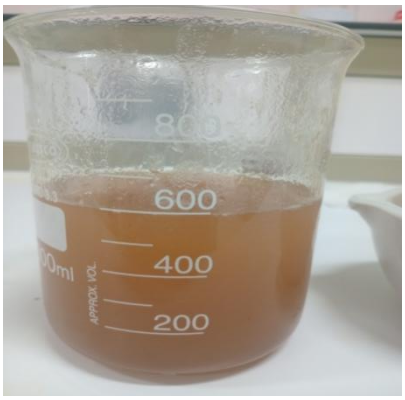


Figure 37: date juice (Deglet Nour) .**(Benchaoui S ; Hamidi A:2025)**

Figure38: date juice (Degla Bayda).**(Benchaoui S ; Hamidi A:2025)**

4. The extraction process was repeated under the same conditions using 200 ml of distilled water to further extract the date juice.

2.Step 02: Centrifugal sediment separation:

The collected extracts were centrifuged at 4000 rpm for 20 minutes to separate the insoluble precipitates and purify the liquid phase.

Figure 39: Centrifugal extraction.**(Benchaoui S ; Hamidi A:2025)**

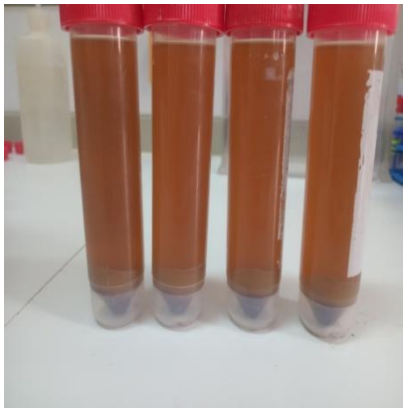


Figure 40: extraction.**(Benchaoui S;Hamidi A:2025)**

3.Step 03: Preparation of sugar syrup:

Sugar syrup contains approximately 80% or more of water and dissolved sugar, along with minerals, etc. To obtain sugar syrup, with little amount of water,it must be evaporated, reducing the sugar and other dissolved substances by 90% or more. For this purpose, this juice is placed in a steam rotary device (LBX, EVA 18 devices) to obtain raw sugar syrup.

Figure41: Preparation of syrup.**(Benchaoui S ; Hamidi A:2025)**

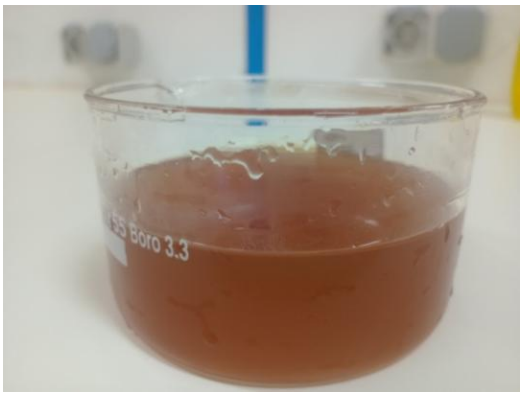


Figure42: Raw sugar syrup.**(Benchaoui S; Hamidi A:2025)**

Then we put the concentrated extracts into Petri dishes, and freeze at 40°C for sufficient time.

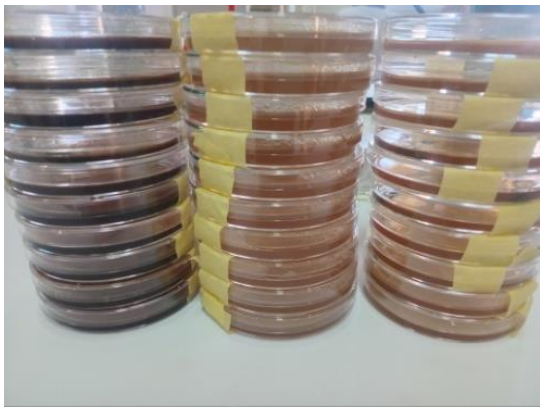


Figure43: Concentrated extract in Petri dishes.**(Benchaoui S ; Hamidi A:2025)**

4.Step 04:Sugar preparation:

The frozen extract is subjected to a freeze-drying process (lyophilization) for 24 hours using a low-pressure lyophilizer, with the aim of removing water without affecting the chemical structure of the sugar.

Figure44: lyophilisateur.**(Benchaoui S ; Hamidi A:2025)**

Figure45: sugar (DB, DN, GH) .**(Benchaoui S ; Hamidi A:2025)**

III.4. Composition of the three sugar extracts:

The three sugar extracts were analyzed for their total sugar, protein and polyphenol content using colorimetric tests.

Each sugar extract (10 mg) was dissolved in 100 ml of distilled water to prepare the solutions, which were then stored at 4°C.

III.4.1. Quantification of Total Sugar Using Dubois Method:

Principle: The total sugar content was determined using the colorimetric method described by (**Dubois *et al*. 1956)**. In this assay, glycosidic linkages are hydrolyzed by concentrated sulfuric acid, resulting in the dehydration of carbohydrate units and the subsequent formation of furfural derivatives. These furfural compounds then undergo a condensation reaction with phenol, producing orange-yellow chromogens that exhibit a maximum absorbance at 492 nm.

Materials and reagents: Phenol (Sigma-Aldrich, PL037) was prepared as a 5% (w/v) aqueous solution. Sulfuric acid (80%, Honeywell, 30743) and aqueous glucose solution (100 µg/mL, Sigma-Aldrich, G8270; with appropriate dilutions) were used. Test samples included DN, DB and GH (0.01%). water bath (SMCLAB QUIMICA, DK- 420), spectrophotometer (JENWAY, 6705 UV/ VIS).

Operating mode:

i. To prepare a 5% phenol solution: mix 1g of phenol with 20 ml of distilled water until fully dissolved.

ii. To prepare a 100 µg/mL glucose stock solution:dissolve 10 mg of glucose in 100 mL of distilled water (Table 12).

Table 10: Preparation of the glucose calibration curve by the Dubois method.

Concentration (%)	White	0.001	0.002	0.005	0.008	0.01
Distilled water (µL)	200	180	160	100	40	0
Glc 100 µg/ml (µL)	0	20	40	100	160	200

iii. Transfer 200 µL of (sample/standard) into glass test tubes and immerse in an ice bath. Add 200 µL of 5% aqueous phenol solution and vortex to mix. Subsequently, introduce 1 mL of 80% sulfuric acid (H_2SO_4) pre-heated to 90°C, maintaining this temperature for 30 minutes. Following incubation, allow samples to equilibrate at room temperature for 30 minutes under light-protected conditions. Finally, quantify absorbance at 490 nm.

III.4.2. Protein determination by the Bradford method:

Principle: Protein content was quantified using the colorimetric method developed by (Bradford .1976). This assay is based on the binding of Coomassie Brilliant Blue G-250 dye to specific amino acid residues within proteins, predominantly arginine, as well as tryptophan, tyrosine, histidine, and phenylalanine. The dye-protein interaction results in a shift in the dye's absorbance maximum, allowing for spectrophotometric measurement of the resulting complex.

Materials and reagents: bovine serum albumin (BSA; Sigma-Aldrich, Cat. No. A2153) at 100 µg/mL, serially diluted in distilled water. Test samples (DB, DN and GH, 0.01% w/v) UV-Vis spectrophotometer (JENWAY, 6705 UV/ VIS).

Operating mode:

i. Bradford Reagent Preparation: To prepare the reagent, first dissolve 100 mg of Coomassie Blue in 50 mL of 95% ethanol. Stir the mixture for 2 hours using a magnetic stirrer, while protecting it from light. Next, add 100 mL of 85% orthophosphoric acid and adjust the final volume to 1 liter with distilled water. Filter the solution through filter paper gto ensure clarity. The prepared reagent is stable for 2 weeks when stored at 4°C.

ii. Preparation of 0.01% BSA Stock Solution: A 0.01% bovine serum albumin (BSA)solution was prepared by dissolving 10 mg of BSA in 100 mL of distilled water **(Table 13).**

Table 11: Preparation of the BSA calibration curve by the Bradford method.

Concentration (%)	White	0.0005	0.001	0.002	0.005	0.008	0.01
Distilled water (µL)	800	760	720	640	400	160	0
BSA 100 µg/ml (µL)	0	40	80	160	400	640	800

iii. Add 500 µL of the sample or standard along with 500 µL of Bradford reagent into the assay tubes. Vortex the mixture for 5 seconds to ensure homogeneity, then incubate at room temperature in the dark for 30 minutes. Finally, measure the absorbance at 595 nm using a spectrophotometer.

II.4.3. Determination of total phenolic compounds :

Principle: The concentration of phenolic compounds is measured using (Singleton *et al*.1999) colorimetric assay. In this method, the Folin-Ciocalteau reagent, composed of sodium phosphomolybdate and sodium tungstate, oxidizes polyphenols, producing tungsten and molybdenum oxides. The reduction of these metal ions results in higher absorbance at 765 nm, enabling the quantification of phenolic content in the sample.

Materials and reagents: The Folin-Ciocalteu reagent (Sigma-Aldrich, F9252) and sodium carbonate (Sigma-Aldrich, S7795). A 10% (w/v) aqueous sodium carbonate solution was prepared as the alkaline buffer. Gallic acid (Sigma-Aldrich, G7384) . The test samples included DB, DN and GH (0.01% each), UV-Vis spectrophotometer (JENWAY, 6705 UV/ VIS).

Operating mode:

i. To prepare a 1/10 dilution of Folin's reagent: mix one part Folin's reagent with nine parts distilled water.

ii. TO PREPARE A 20% SODIUM CARBONATE SOLUTION: DISSOLVE 20 G OF SODIUM CARBONATE IN DISTILLED WATER TO MAKE A FINAL VOLUME OF 100 ML.

iii. To prepare a 0.1% (w/v) gallic acid stock solution: accurately weigh 100 mg of gallic acid and dissolve it in distilled water to a final volume of 100 mL (Table 14).

Table 12: Preparation of the gallic acid calibration curve using the Singleton method.

Concentration (%)	White	0.0005	0.001	0.0015	0.002	0.0025	0.003	0.0035
Distilled water (µL)	100	95	90	85	80	75	70	65

Acide gallique 100 µg/ml (µL	0	5	10	15	20	25	30	35

iv. Add 100 µL of sample and 500 µL of Folin's reagent to the assay tubes, mix gently, and allow to stand for 3 minutes. Next, add 2 mL of sodium carbonate solution, vortex for 10 seconds, and incubate the mixture in the dark at room temperature for 1 hour. Finally, measure the absorbance at 765 nm.

III.5. Physico-chemical characteristics:

III.5.1. Humidity level :

Principle: This test aims to determine the moisture content of a sample, which is measured based on the mass loss after drying. This loss includes not only water but also other volatile substances such as alcohols, oils, organic solvents, aromatic compounds, and even decomposition and thermal decomposition products. The sample is heated in an oven at 110°C for 6 hours, and the difference in mass is then calculated to estimate the moisture content **(Belibi *et al*., 2014)**.

Materials and reagents: analytical balance for weighing samples, a drying oven (POL-EKO SP.K.) set to 110°C, heat-resistant aluminum or glass containers for storing samples, and metal tongs for safe handling of hot containers.

Operating mode:

i. The moisture content of the samples was determined using a constant-temperature oven drying technique according to the approved method. The samples were first weighed and then oven-dried at 110°C for 6 hours. After drying, the samples were cooled in a desiccator to maintain dryness and reweighed after cooling.

ii. Moisture content was determined based on the difference between the weight before and after drying.

III.5.2. Mineral:

Principle: This method relies on burning the sample in a Muffle furnace at a high temperature of 500°C to completely remove the organic matter. After burning, the inorganic ash (minerals) is weighed, and this weight is used to estimate the total mineral content or to prepare the sample for further analysis, such as atomic absorption spectroscopy **(AFNOR, 1982)**.

Materials and reagents: A Muffle furnace at 500°C was used to incinerate the samples and remove organic matter.

Operating mode:

i. 0.5 g of sugar was accurately weighed and placed in a clean, dry ceramic crucible.
ii. The crucible was placed in a muffle furnace set at 500°C for 3 hours, until the sample turned to a gray, white, or black ash.
iii. After burning, the crucible was removed using metal tongs and placed in a glass desiccator to cool and avoid moisture absorption, and the remaining ash was then accurately weighed.

III.5.3. PH:

Principle: The aim of this analysis is to determine the pH of a sugar solution extracted from dates. pH is used as an indicator of the chemical nature of the medium (acidic, neutral, or basic), helping to assess the properties and quality of the extracted sugar. This is performed using a pH meter equipped with a glass electrode, which provides a direct digital reading after the signal stabilizes in a dilute sugar solution**(Pakale*et al*,. 2018)**.

Materials and reagents: A digital pH meter (consort- C3010) equipped with a glass electrode was used to accurately measure the pH,

Operating mode:

i. The glass electrode of the pH meter is washed with distilled water and gently dried with clean filter paper to remove any residue that might affect the accuracy of the measurement.
ii. The glass electrode is immersed in the sugar solution and waited for the reading to stabilize on the meter's screen. The final pH value is then accurately recorded.

III.5.4. conductivité :

Principle: The electrical conductivity of the solution was measured by immersing a probe into the sample. The probe contains two electrodes that pass a low electrical current through the solution. Dissolved ions in the solution move in response to this current, and the solution's ability to conduct current (i.e., its conductivity) is recorded by the instrument. Electrical conductivity

depends on the concentration of ions in the sample; the higher the concentration, the higher the conductivity. After the reading stabilized, the value was displayed directly on the instrument screen in microsiemens per centimeter (µS/cm) **(Radiometer Analytical, 2004).**

Materials and reagents: A conductivity meter (consort- C3010) equipped with a probe containing two electrodes was used to measure the conductivity of the sugar solution.

Operating mode:

Measurement procedure: The device was turned on, the probe was cleaned, and then immersed in the liquid sample until the reading stabilized. The electrical conductivity value was recorded in µS/cm.

After measurement: The probe was cleaned with distilled water and dried thoroughly.

III.6. Structural characterization of the sugar extracts

III.6.1. Infrared spectroscopy (FT-IR):

Principle: Fourier-transform infrared spectroscopy (FT-IR) is an absorption-based analytical technique used to identify the functional groups within a compound. When exposed to infrared (IR) radiation, chemical bonds absorb specific wavelengths depending on their structure and configuration. The resulting spectrum provides characteristic peaks that help distinguish different molecular constituents, such as OH, CH, and C-C groups. FT-IR is especially useful for studying organic biological samples, including sugar . The typical IR analysis range spans from 4000 cm^{-1} to 400 cm^{-1}, covering vibrational and rotational molecular transitions. Since this range captures most spectral signatures of organic molecules in living systems, it is highly effective for sugar analysis **(Keirsse, 2003)**.

Materials and reagents:Potassium bromide (KBr). Fourier-transform infrared (FT-IR) spectroscopy Nicolet iS5 spectrometer (Thermo Fisher Scientific).

Operating mode: Infrared (IR) spectroscopy was employed to analyze the functional groups present in the sugar extracts. The IR spectra of all fractions were measured using a spectrophotometer with potassium bromide (KBr) discs, covering a wavelength range of 400 to 4000 cm^{-1}. For sample preparation, 2 mg of the dried sugar extract was mixed with 200 mg of dry KBr and pressed into a pellet for spectral analysis. This technique offers accurate insights into the chemical structure of sugar by detecting characteristic functional groups and examining molecular vibrations **(Keirsse, 2003)**.

III.6.2. Determination of constituent sugar the composition by (HPLC):

Principle:High-performance liquid chromatography (HPLC) operates on the principle of separating mixture components in solution using a chromatography column packed with porous stationary particles, such as silica or octadecylsilyl. Separation occurs due to the differential affinity of the components for the mobile phase (the solvent) and the stationary phase (the column packing), leading to variations in retention times and distribution within the column **(Anderson *et al*., 2015).**

The process begins by dissolving the sample in the mobile phase, which is then injected into the column. As the mobile phase flows continuously through the column, it carries the mixture's components, which separate based on their interactions with the stationary phase. These components elute at different times and are detected by an appropriate detector, such as UV, fluorescence, or mass spectrometry, depending on the compounds' properties and required sensitivity **(Anderson *et al*., 2015).**

The mobile phase can consist of a single solvent or a tailored mixture, selected based on the target compounds. Additionally, parameters like pH, salt concentration, and temperature can be fine-tuned to enhance separation efficiency **(Meyer, 2010).**

Materials and reagents: Ultrapure water and acetonitrile (Honeywell) were used as solvents. The following standards were obtained from Sigma-Aldrich: D-glucose (Cat. No. G8270), D-fructose, Saccharose. The samples (DB, DN, GH) were prepared at a concentration of 50 mg/mL.

Operating mode:

i. The sugar DB, DN and GH were analyzed via high-performance liquid chromatography (HPLC) based on the method by Tihomirova *et al*. (2016), with minor modifications. The analysis employed an NH2 column (150 mm × 4.6 mm inner diameter, 5 µm particle size) maintained at 35°C. Isocratic elution was carried out at a flow rate of 1 mL/min using a mobile phase of acetonitrile (solvent A) and ultrapure water (solvent B) in an 80:20 (v/v) ratio. Detection was achieved using a refractometric detector.

ii. the composition standards, were dissolved in ultrapure water to identify the composition of the three extracts. In HPLC analysis, peak assignment was performed by comparing the retention times of the sample peaks with those of the reference standards.

iii. To quantify thecomposition in the extracts, the peak areas of the reference compounds were measured. Based on these values, the percentage of each sugar in the extracts were calculated.

III.6.3. Atomic absorption spectroscopy:

Principle: Atomic absorption is the phenomenon by which an atom in its ground state absorbs electromagnetic radiation at a specific wavelength, corresponding to its resonance frequency, and transitions to an excited state. This absorption causes a measurable attenuation of the transmitted radiation

In atomic absorption spectrometry, free atoms of the element to be analyzed are generated from the sample (by atomization in a flame). Light, emitted by a hollow cathode lamp specific to the element, passes through this atomic vapor. The amount of light absorbed at a resonance line is proportional to the concentration of the element, according to the Lambert-Beer law **(Beaty*et al*,.1978)**.

Materials and reagents: In this experiment, an atomic absorption spectrometer (Sherwood M410) was used to analyze the content of certain mineral elements in the sugar extracts (DB, DN, GH). The materials used included: pre-prepared liquid samples (sugar extracts) and distilled water used to clean the instrument and tubes before and after analysis.

Operating mode: The **atomic absorption spectrometer** (Sherwood M410) was operated in **flame atomic absorption mode**, using an **air-acetylene flame** as the energy source. The analysis was conducted in **direct measurement mode**, without the use of standard calibration solutions.

III.7. Chocolate production using sugar dates:

III.7.1. Preparing date paste:

The same methodology used in the laboratory for sugar extraction from dates was followed, with some minor modifications. The main difference is the absence of freeze- instead, the extraction was carried out under normal household conditions, unlike the controlled conditions of the laboratory.

III.7.2. Chocolate making:

III.7.2.1.Semi solid chocolate:

Table 13: Proposed Percentage Composition of Semi solid Chocolate.

Ingredient	Quantity(%)
Date sugar	60 %
cocoa powder	20 %
Hazelnut	20 %

Figure46: Semi solid chocolate.**(Benchaoui S ; Hamidi A:2025)**

III.7.2.2. Solid chocolate:

Table 14: Proposed Percentage Composition of Solid Chocolate.

Ingredient	Quantity(%)
Date sugar	20 %
cocoa powder	20 %
Hazelnut	20 %
Cocoa butter	40 %

Figure47 : solid chocolate.**(Benchaoui S ; Hamidi A:2025)**

III.7.3. Questionnaire :

A questionnaire was distributed to two groups of participants to evaluate the semi solid and solid chocolate made with date sugar, and to gather information about their preferences and various uses.

For the liquid chocolate, **75 people** were surveyed, ranging in age from **18 to 70 years old**, including **40 women** and **35 men**.

For the solid chocolate, **60 people** participated in the survey, also ranging in age from **18 to 70 years old**, including **40 women** and **20 men**.

Each questionnaire included an evaluation of the semi solid and solid chocolate products, covering aspects such as taste, texture, aroma, and overall appearance, in addition to consumer preferences regarding ingredients like date-derived sucrose, and their overall satisfaction with the product experience **(Table 15) (Acourene *et al*,. 2001)**.

Table 15: Organoleptic test of the chocolate produced **(Acourene *et al*,. 2001).**

	Very poor(1)	Poor (2)	Middle (3)	Above the middle (4)	Good (5)	Very Good (6)	Good (7)	Very Good (8)	Excellent (9)
The smell									
Flavor									
Sweetness									
Acidity									
Bitterness									
Holding									
Acceptance									

Chapter IV: Results and discussion

IV. Results and discussion:

This chapter represents the results of sugar extracted from three date varieties (Deglet Beida, Deglet Nour, and Ghars), along with the evaluation of their physico-chemical properties. The findings aim to assess the potential of these extracts in enhancing chocolate production, based on precise analytical comparisons between the selected varieties.

VI.1. Extraction yields:

Aqueous extracts from three *Phoenix dactylifera* L. cultivars (DB, DN, and Gh) collected from Djamaa (El Meghaier, Algerian Sahara), were subjected to freeze-drying using a lyophilizer. This process enabled the sublimation of water and yielded concentrated dry extracts rich in water-soluble compounds, primarily sugars.

Figure 48: Date sugar prepared using a lyophilizer from *Phoenix dactylifera* L. varieties:(Gh, DN, and DB) .**(Benchaoui S ; Hamidi A:2025)**

The extraction yields varied significantly among the three studieddate varieties. Gh exhibited the highest extraction yield, reaching 52.8%, followed by DB at 42.8%, while DN had the lowest yield with only 28.8%. This indicates that Gh contains a higher proportion of extractable components, likely due to its softer texture and higher moisture content, which facilitates solvent penetration and solubilization of bioactive compounds.

These results are in line with findings reported by **(Al-Farsi *et al*;2021),** who observed that soft date varieties generally yield higher extraction percentages due to their matrix properties and solubility of constituents. In contrast, hard or semi-dry varieties like DN typically demonstrate lower yields, a trend confirmed in the study by **(El Sohaimy *et***

***al*;2020),** where DN showed a significantly lower extraction yield compared to other Algerian date cultivars.

Moreover, the moderate yield observed in DB may be attributed to its intermediate textural characteristics and biochemical composition, positioning it between the soft Gh and the drier DN. This aligns with the data of **(Bouhlali *et al*;2022)**, who highlighted the impact of varietal differences on extraction efficiency, especially due to variations in sugar content, fiber, and phenolic distribution.

These differences underscore the importance of cultivar selection in optimizing extraction protocols for bioactive compounds recovery, particularly when targeting industrial or nutraceutical applications.

VI.2. Chemical compositions of date samples:

VI.2.1. Quantification of Total Sugars, Polyphenols, and Proteins :

The percentage content of total sugars, polyphenols, and proteins was determined in the aqueous extracts of three date fruit varieties (*Phoenix dactylifera*): (Gh, DB, and DN), as presented in Table (18). The results showed that the percentage of total sugars varied across the samples, with DB recording the highest value (87.22%), followed by Gh (77.89%), and DN (66.70%). This variation may be attributed to cultivar-specific metabolic differences under identical extraction conditions.

In contrast, polyphenols content showed a range of variation. DB recorded the highest percentage (0.663%), followed by Gh (0.541%), while DN exhibited the lowest value (0.455%). Regarding proteins, Gh showed a relatively higher value (0.960%), compared to DB and DN (0.663% and 0.455% respectively). These variations reflect potential biochemical and physiological differences among the cultivars under the given extraction conditions.

These findings are consistent with previous studies. Gh, with its dark color and soft texture, is known for its elevated metabolic activity, which may also explain its relatively high protein content **(El Arem *et al*., 2014; Amira *et al*., 2012)**. DN, which has a balanced flavor and semi-dry texture, showed moderate levels of both polyphenols and proteins, aligning with its intermediate ripeness and enzymatic **profile (Habib *et al*., 2021)**. On the other hand, the low polyphenols and proteins contents in DB may be due to its light color and limited phenolic breakdown, as indicated by **(Al-Harrasi *et al*., 2020).**

As for sugars, the recorded percentages (66.70% to 87.22%) fall within the typical range for date extracts, which usually spans between 20% and 90% depending on the cultivar and ripening stage **(Assirey, 2015; Biglari *et al.*, 2009**). Similarly, the proteins levels align with findings from **(Sait *et al.*, 2022)**, who reported values ranging from 0.3% to 1.0% in aqueous date extracts. These biochemical variations highlight the importance of selecting appropriate cultivars when evaluating the nutritional and functional properties of date-based products for food or therapeutic purposes.

Table 16: Percentage of Total Sugars, Polyphenols, and Proteins in Aqueous Extracts of Date Varieties

Compound	Ghars (%)	Deglet Beida (%)	Deglet Nour (%)
Total Sugars	77.89±1.68	87.22±2.43	66.70±0.42
Polyphenols	0.541±0.168	0.663±0.0042	0.455±0.091
Proteins	0.960±0.056	0.663±0.0042	0.445±0.091

VI.3. physico-chemical characteristics:

VI.3.1. Humidity leve:

Moisture content is one of the essential parameters in evaluating the physical quality and shelf life of dates. In this study, the moisture levels of three date varieties Al-Gharas, Deglet Nour, and Deglet Beida were determined by weighing 1 g of each sample and recording the weight loss due to water evaporation.

Table17: Moisture Content of Different Date Varieties Used in the Study

Date Variety	Moisture Content (%)
Al-Gharas	29
Deglet Nour	22
Deglet Beida	19

The results showed that Gh had the highest residual moisture, with a weight loss of 0.29 g (29%), followed by DN at 0.22 g (22%), while DB recorded the lowest moisture loss at 0.19 g (19%).

These values do not represent the total moisture content of the original date fruits, but rather the moisture retained in the sugar extracts after extensive processing. Therefore, they are naturally lower than the values typically reported in the literature for whole dates. For instance, **(Ben Salah *et al*;2022)** reported moisture levels ranging between 70–80% for Gh and 55–65% for DN, while DB showed less than 50% due to its semi-dry characteristics. Similarly, **(Ammar *et al*;2021)** highlighted that moisture variation is influenced by environmental conditions, ripening stage, and post-harvest drying methods.

Despite the difference in measurement context, our results maintain the relative trend observed in previous studies, with Gh exhibiting the highest moisture content, followed by DN and DB. This consistency supports the classification of Gh as a soft variety, DN as semi-soft, and DB as semi-dry, even at the extract level.

VI.3.2. Salt level:

Salt content is a key parameter in the physical assessment of dates, as it directly influences quality and storage potential. In this study, the salt levels of three date varieties (Gh, DB, and DN) were measured using a Fouremouffer moisture analyzer adapted for total soluble solids estimation.

Table 18: Salt percentage in Three Date Varieties:(Gh, DB, and DN)

Date Variety	Salt (%)
Al-Ghars	23.5
Deglet Baeida	3
Deglet Nour	7

The results of the salt content analysis revealed significant variation among the three studied date cultivars. The Gh variety recorded the highest salt content at approximately 23.5%, followed by DN with an estimated value of around 7%, while DB had the lowest salt content, not exceeding 3%. These findings reflect the differences in the physical and chemical composition of the varieties, as Gh is known for its high concentration of soluble solids and mineral content, compared to the lower levels found in DN and DB.

These results are consistent with the findings of **(Ben Salah *et al*., 2022),** who reported that Gh dates generally contain between 20–25% total soluble solids, including salts, compared to 7–10% in DN, which closely aligns with our data. Another study by **(Ammar *et al*., 2021)** supported these differences, noting that variations in salt content are influenced by several factors such as climatic conditions, ripening stage, and post-harvest practices.

It is worth noting that the low salt content in DB may be explained by its classification as a semi-dry variety typically cultivated in arid regions or subjected to traditional practices that reduce mineral retention. This makes it more suitable for long-term storage compared to Gh, which is usually consumed fresh and contains higher soluble residue.

From an industrial perspective, salt content directly impacts the shelf life, flavor profile, and preservation stability of the product, highlighting the importance of such parameters in guiding the commercial use of each variety.

VI.3.3. Mineral:

The total mineral content of the date fruit samples was determined using Electrothermal Vaporization (ETV). The results revealed noticeable differences between the three varieties. Both DB and DN exhibited the highest mineral content, each recording 2.2%, whereas Gh had a significantly lower content of 0.8%

Table 19: Total Mineral Content (%) in Three Date Varieties Measured by Electrothermal Vaporization (ETV)

Date Variety	Total Mineral Content (%)
Deglet Beida	2.2
Ghars	0.8
Deglet Nour	2.2

The similarity between DB and DN in total mineral concentration may be attributed to their classification as semi-dry date varieties, which are known to retain higher mineral levels due to their denser tissue structure and lower moisture loss during maturation. This observation is in agreement with findings by (**Habib *et al*. ;2013)**, who reported higher mineral retention in semi-dry dates compared to soft ones.

On the other hand, the lower value observed in Gh, a soft and more hydrated variety, is likely due to greater water content, which results in the dilution of mineral concentration. **(Al-Farsi and Lee;2008)** highlighted similar findings, noting that soft dates tend to have reduced mineral density due to water accumulation in the later stages of ripening.

Overall, the mineral content values reported here fall within the general range documented in literature (0.5–2.5%), affirming the role of dates as a good dietary source of essential minerals such as potassium, calcium, and magnesium **(Al-Shahib & Marshall;2003)**. These differences can be crucial in tailoring date consumption for specific nutritional requirements.

VI.3.4. PH:

The pH values of three date fruit varieties (DB, DN, and Gh) were measured, revealing slight differences among the samples. DB recorded a pH of 5.55, followed by DN with 5.52, while Gh showed the highest pH at 5.60.

Table 20: pH Values of Three Date Fruit Varieties

Variety	pH Value
Deglet Beida	5.55
Deglet Nour	5.52
Ghars	5.60

These values fall within the mildly acidic range (5–6), consistent with findings by **(Al-Farsi *et al*;2007),** who reported that most date varieties tend to have a near-neutral to slightly acidic pH due to relatively low concentrations of organic acids, especially at advanced ripening stages.

Among the three, DB showed the least acidity, with a pH of 5.55, approaching neutrality. This suggests favorable sugar stability characteristics, as confirmed by **(Habib *et al*;2014).** A lower acidity environment helps minimize the acid-catalyzed hydrolysis of sucrose and preserves the structure of reducing sugars like glucose and fructose, enhancing sweetness and storage quality.

Although Gh had the highest pH value (5.60), this may be attributed to its soft texture and fully ripened state, which typically involves higher sugar content and lower organic acid levels. This aligns with observations by **(Saafi *et al*;2011),** who noted that soft, ripe date varieties often display reduced acidity.

Overall, the recorded pH values indicate that all three date samples maintain a relatively mild chemical environment, making them suitable for direct consumption, industrial processing, and storage without requiring major pH adjustments in products such as date paste or gum.

VI.3.5. Conductivity :

Electrical conductivity (EC) was measured in aqueous extracts of three date fruit varieties to estimate the total soluble salt content. The results revealed clear differences between the samples. DN showed the highest salt concentration (approximately 1.92%), followed by Ghars (1.37%), and DB (0.94%), as shown in Table (05).

Table 21: Soluble Salt Content in Date Extracts (Estimated from Electrical Conductivity)

Variety	EC (mS/cm)	Soluble Salt Content (%)
Deglet Nour	30.01	1.92
Ghars	21.40	1.37
Deglet Beida	14.71	0.94

Electrical conductivity reflects the presence of dissolved ions such as potassium, sodium, and calcium, as well as ionizable sugars. The high EC value in DN indicates a rich ionic composition. **(Al-Farsi *et al*;2007)** noted that EC serves as an indirect but effective indicator of the quality and mineral balance.

Gh, a soft-textured variety rich in reducing sugars, presented a moderate salt percentage, supporting findings by **(Habib *et al*. (2014)**, who established a direct relationship between EC and the presence of soluble sugars.

In contrast, DB recorded the lowest salt content, indicating a more stable chemical profile. This suggests greater suitability for storage and potential applications in food processing, such as in pastes or extract formulations.

IV.4. Structural characterization of the sugar extracts:

IV.4.1. Infrared spectroscopy (FT-IR):

The FT-IR spectra of the aqueous extracts of the three date varieties (DN, DB, and Gh) revealed the presence of key functional groups characteristic of sugars.

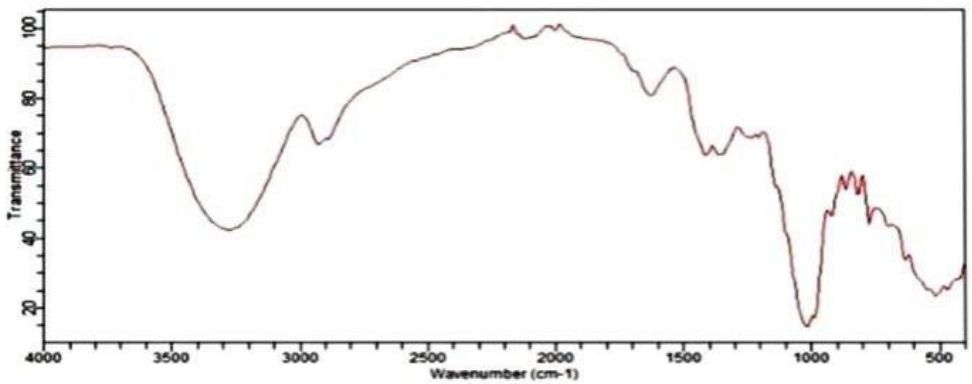


Figure 49: Infrared spectroscopy (FT-IR) of Deglet Beida Date Sample

A broad and strong absorption band appeared at approximately 3300–3400 cm^{-1}, which corresponds to the O–H stretching vibrations, typical of hydroxyl groups in water and carbohydrates. This indicates a high content of free and bound water, as well as the abundance of polyhydroxylated compounds such as glucose and fructose.

A medium intensity band was detected near 2900 cm^{-1}, assigned to the C–H stretching vibrations, suggesting the presence of aliphatic chains common in sugar molecules. Another distinct peak observed at approximately 1650 cm^{-1} is attributed to the C=O stretching vibration, possibly originating from carbonyl groups in reducing sugars like glucose and fructose.

Notably, sharp peaks in the range of 1050–950 cm^{-1} were recorded across all samples. These are characteristic of C–O and C–C stretching vibrations in carbohydrates. This region is particularly indicative of the presence of α-glucopyranose (around 1025 cm^{-1}) and β-fructofuranose (around 980 cm^{-1}). The appearance of both sugar forms is evident in this range due to the differences in ring structure and conformation, with each form producing slightly distinct vibrational frequencies.

These observations align with the findings of **(Kamil *et al*;2015)** and **(Al-Farsi *et al*;2020)**, who confirmed that the intense absorption bands in this fingerprint region are reliable indicators of sugar content and their structural forms in date fruits.

A comparative analysis of the three varieties showed a high degree of similarity in spectral patterns, yet differences in band intensity suggest variation in sugar concentration, particularly in glucose, fructose, and sucrose. These differences were further supported by the quantitative HPLC analysis.

The presence of both α-glucopyranose and β-fructofuranose is significant, as it reflects the dynamic equilibrium between different cyclic forms of sugars in aqueous solution. These structural forms are known to influence the sweetness and metabolic behavior of sugars in biological systems.

To visualize the comparison, all three spectra were superimposed in a single FT-IR graph, allowing for direct observation of overlapping peaks and relative intensities. This strategy was chosen due to the comparable spectral profiles, as also recommended in related studies where spectra of similar matrices were analyzed together **(Zhang *et al*., 2021).**

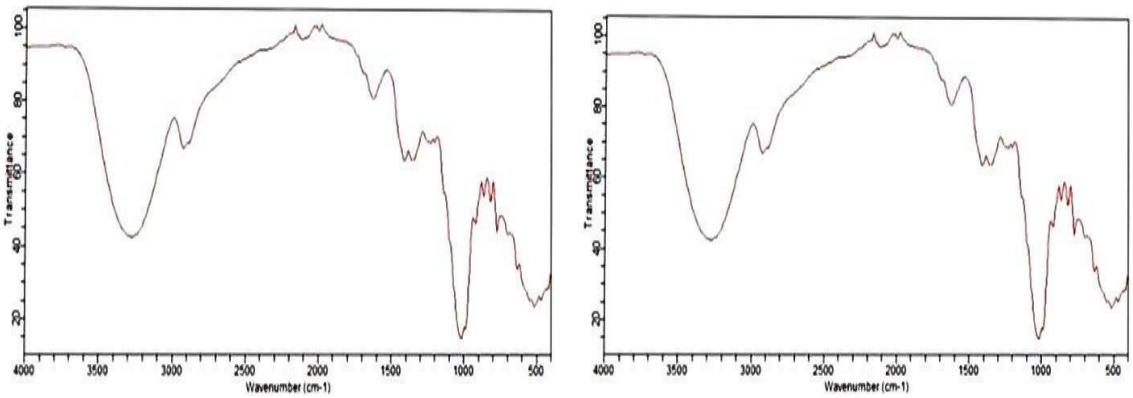


Figure50et 51: Infrared spectroscopy (FT-IR) of (Gh and DN) Date Sample

IV.4.2. Determination of constituent sugar the composition by (HPLC):

The HPLC chromatograms recorded for the three date varieties (DB, Gh, and DN) display clear separation of the main sugars: fructose, glucose, and sucrose.

Table 22: Sugar Composition, Retention Time, and Proportion in Date Varieties Based on HPLC Analysis

Sample	Sugar Type	Retention Time (min)	Concentration (unit)	Proportion (%)
Deglet Beida	Fructose	5.904	20.29	31.6
	Glucose	6.337	27.89	43.3
	Sucrose	8.564	16.03	25.0
Ghars	Fructose	5.893	7.63	27.4
	Glucose	6.316	20.25	72.6
	Sucrose	—	0.00	0.0
Deglet Nour	Fructose	5.891	31.88	48.5
	Glucose	6.312	28.44	43.3
	Sucrose	8.138	5.38	8.2

The retention times closely matched those of known standards, confirming the identification reliability.

Fructose appeared between 5.891 and 5.904 min, glucose between 6.312 and 6.337 min, and sucrose between 8.138 and 8.564 min. DB (Sample 1) exhibited the highest total sugar content. Fructose was dominant, comprising 48.5% (31.88 units; R_t = 5.904 min), followed by glucose at 43.3% (28.44 units; R_t = 6.337 min), and sucrose at 8.2% (5.38 units; R_t = 8.564 min). This profile suggests a mature fruit with partial sucrose hydrolysis, consistent with findings by **(Habib *et al.*, 2014),** who observed elevated levels of reducing sugars in ripe dates.

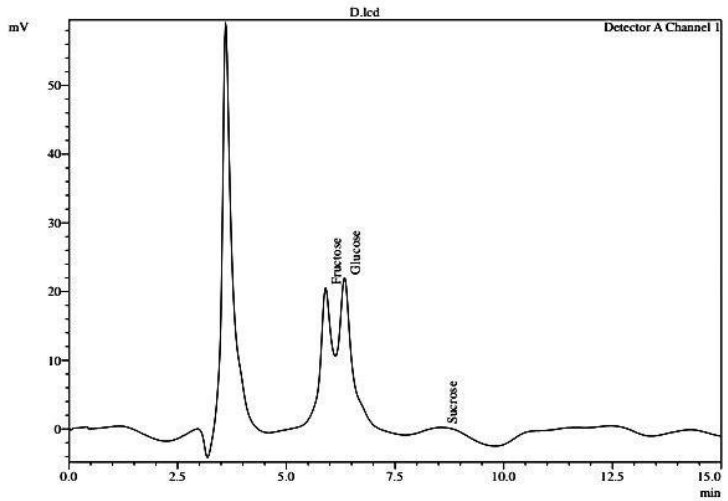


Figure 52: Proportions of Fructose, Glucose, and Sucrose in DB (D.lcd) by HPLC.

Gh (Sample 2) showed a high glucose proportion (43.4%, 27.89 units; R_t = 6.316 min), followed by fructose at 31.6% (20.29 units; R_t = 5.893 min), and sucrose at 25.0% (16.03 units). Although complete sucrose hydrolysis was expected, its presence indicates incomplete ripening or moderate enzymatic activity. This partially aligns with **(Besbes *et al.*, 2009),** who reported an absence of sucrose in fully ripe Gh dates.

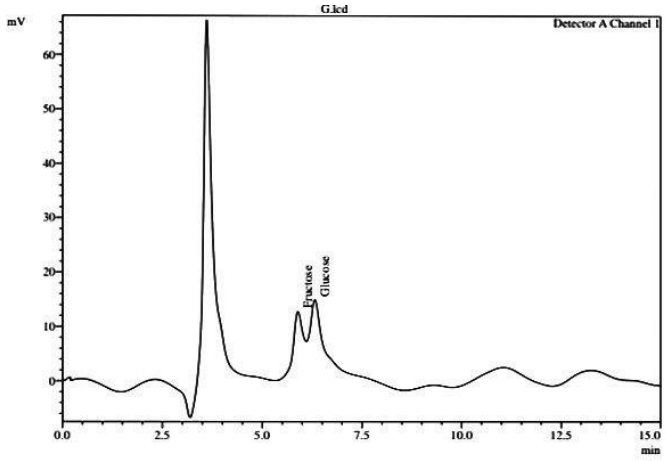


Figure53: Proportions of Fructose, Glucose, and Sucrose in Gh (G.lcd) by HPLC.

DN (Sample 3) was characterized by a very high glucose content (72.6%, 20.25 units; R_t = 6.312 min), with fructose contributing 27.4% (7.63 units; R_t = 5.891 min), while sucrose was not detected. This suggests advanced ripening and full transformation of sucrose. Interestingly, **(Saafi *et al.*, 2011)** previously noted that DN tends to retain sucrose unless harvested at a late stage.

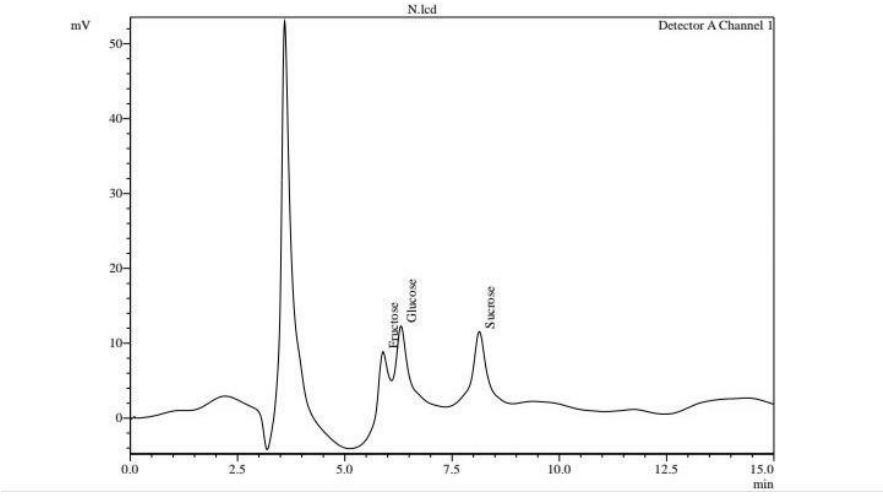


Figure 54: Proportions of Fructose, Glucose, and Sucrose in DN (N.lcd) by HPLC.

VI.4.2.1 Comparative Chromatographic Overview:

lative percentage of fructose, glucose, and sucrose in DB, Gh, and DN date cultivars, based on HPLC analysis. DB shows a balanced composition of monosaccharides with low sucrose. Gh contains the highest proportion of sucrose among the three. DN lacks sucrose completely, indicating advanced hydrolysis of disaccharides into monosaccharides.

IV.4.3. Atomic Absorption Spectroscopy of date samples:

The percentage composition of mineral elements (calcium, sodium, and potassium) in the analyzed date samples (DB, Gh, and DN). The results revealed noticeable variation among the cultivars, as detailed in the following table:

Table 23: Percentage composition of mineral elements in date fruit samples(DB, Gh, and DN).

Sample	Calcium (Ca^{2+}) (%)	Sodium (Na^{+}) (%)	Potassium (K^{+}) (%)
Deglet Beida	0.00025	0.00044	0.066
Ghars	0.00025	0.00009	0.0165
Deglet Nour	0.00025	0.00009	0.00825

IV.4.3.1. Potassium (K^{+}):

A notable difference in potassium levels was observed. DB had the highest potassium percentage (0.066%), followed by Gh (0.0165%) and DN (0.00825%). These values are relatively low when compared to previous studies, which reported potassium contents of up to 851.98 mg/100 g in Medjool dates **(Bouhlali *et al.*, 2019)** and 656 mg/100 g in DN. Such discrepancies can be attributed to genetic factors, post-harvest processing, or dilution effects from sample preparation.

IV.4.3.2. Sodium (Na^{+}):

Sodium levels varied, with DB showing the highest percentage at 0.00044%, while Gh and DN exhibited much lower values (0.00009% each). This variation may reflect differences in the cultivars' capacity to absorb or accumulate sodium, a pattern also supported by

(Nasution *et al*;2021), who highlighted the influence of soil and irrigation on mineral uptake in dates.

IV.4.3.3. Calcium (Ca^{2+}):

The calcium content was found to be consistent across all three samples at 0.00025%, indicating a similar distribution of this element among the cultivars studied. In comparison, previous studies such as **(Bouhlali *et al*;2019)** reported significantly higher values (e.g., 129.14 mg/100 g in Medjool dates), likely due to cultivar differences, environmental factors, or analytical methods used.

These differences in mineral distribution underscore the nutritional diversity among date cultivars, making certain varieties more suitable for dietary applications aimed at addressing specific mineral deficiencies.

VI.5. Chocolate production using sugar dates:

VI.5.1. Chocolate making:

VI.5.1.1. Semi solid chocolate:

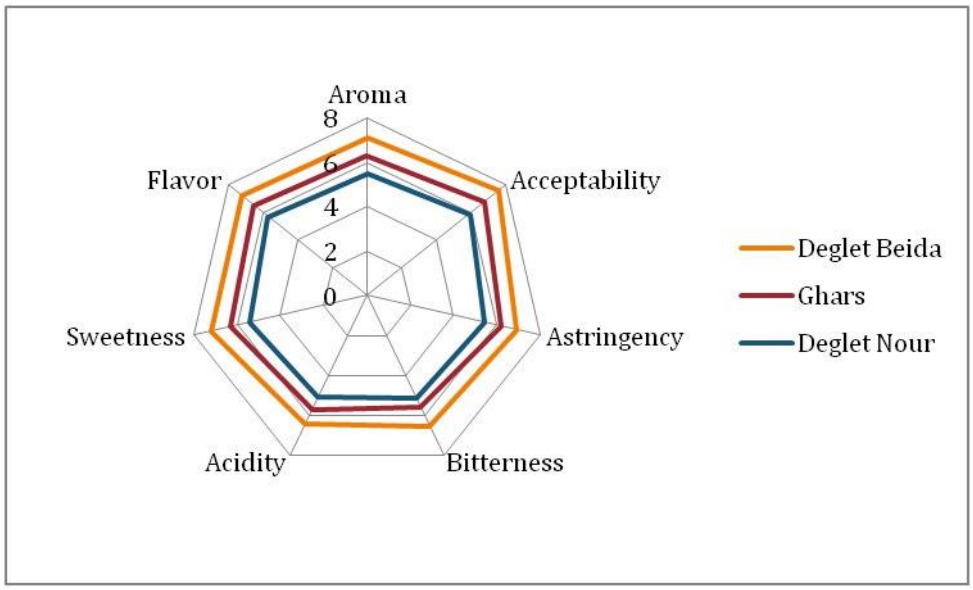


Figure ٥٥: Sensory Evaluation Radar Chart of Semi solid Chocolate Sweetened with Date Sugar from Three Date Varieties

The radar chart illustrates the sensory evaluation results of semi solid chocolate sweetened with date sugar derived from three different date varieties: DB, Gh, and DN. The

products were assessed based on seven sensory attributes: aroma, acceptability, astringency, acidity, bitterness, sweetness, and flavor.

In the semi solid chocolate formulations, DB continued to demonstrate superior sensory performance, especially in sweetness, flavor, and acceptability. Its balanced sugar composition and low moisture contributed to a smooth mouthfeel and pleasant sweetness. As with the solid form, the pH (5.55) showed no significant sensory influence due to the narrow pH range among the samples, suggesting that sugar structure and moisture played more prominent roles **(Nasser *et al*., 2023).**

Thechocolate made with Gh sugar showed improved sensory ratings. The high moisture in the semi solid matrix allowed better solubility ofreducing sugars, leading to a more acceptable taste profile. This aligns with **(Al-Khalifa *et al*;2021),** who reported that moisture plays a critical role in maskingacidity and enhancing sweetness in moist food systems.

As for DN, it continued to show the lowest sensory performance. Despite having acceptable moisture and pH(5.52), the lack of distinct aroma and flavor compounds limited its overall sensory appeal **(El-Maaref *et al*., 2021).**

VI.5.1.2. solid chocolate:

The radar chart presents the sensory evaluation outcomes for solid chocolate sweetened with date sugar obtained from three varieties: (DB, Gh, and DN). Evaluation attributes include aroma, acceptability, astringency, acidity, bitterness, sweetness, and flavor.

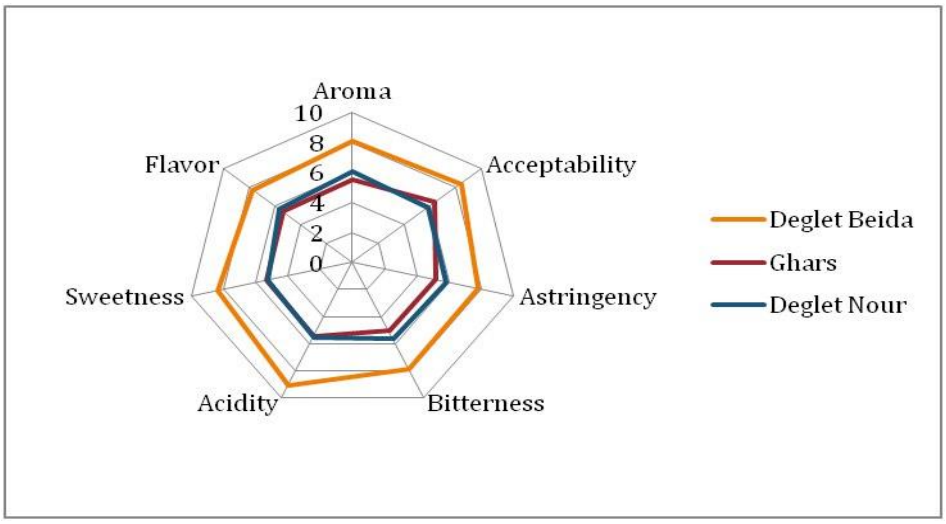


Figure 56: Sensory Evaluation Radar Chart of Solid Chocolate Sweetened with Date Sugar from Three Date Varieties

Sensory evaluation results revealed that the chocolate made with DB date sugar outperformed the others in most sensory attributes, including sweetness (8.4), appearance (9.1), astringency (7.8), and overall acceptability (8.4). This superiority can be attributed to several analytical factors, notably the low moisture content (3%), which improved product stability and appearance. While its pH was 5.55, similar to the other samples, the differences in flavor perception are more likely due to its high sucrose content, which provides a clean and balanced sweetness without overpowering acidity **(Rahman *et al*., 2022)**.

In contrast, chocolate made with Gh sugar scored lower in attributes such as sweetness (5.2) and appearance (5.5). Although its pH was slightly higher (5.60), the high moisture content (23%) likely affected the solid structure of the chocolate, leading to less favorable astringency and mouthfeel. Moreover, the high concentration of reducing sugars such as glucose and fructose may have contributed to a heavier and less clean flavor profile, consistent with the findings of **(Al-Khalifa *et al*., 2021)**.

Chocolate made with DN date sugar received the lowest sensory ratings in sweetness (4.3) and aroma (5.3). Despite having a moderate moisture level (7%) and pH of 5.52, the lower presence of aromatic and flavor compounds in this date variety appears to have limited its sensory impact **(El-Maaref *et al*., 2021)**.

Sensory differences among the chocolate samples were not significantly influenced by pH, given their close values (5.52–5.60). Instead, moisture content, sugar composition (sucrose vs. reducing sugars), and aromatic compound profiles played major roles in shaping sensory perception. Overall, DB date sugar appears to be the most suitable option for both solid and liquid chocolate formulations in terms of sensory quality.

Conclusion

Conclusion

The objective of this studyis to identify and characterize the physical and chemical properties of water-soluble sugars extracted from three date varieties: Deglet Nour, Ghars, and Degla Beida, harvested in the Djamaa region, located in the El M'Ghair province in the northern Algerian Sahara. This work is part of a broader study aiming to evaluate the potential use of date sugar as a natural alternative to industrial sucrose in chocolate production. Extraction was carried out using a simple aqueous method, with certain experimental steps conducted both at home and in the laboratory. The studied date varieties showed variation in extraction yield and in the chemical characteristics of the obtained sugar, reflecting the natural diversity among cultivars.The extracts were subjected to comprehensive physicochemical analyses, including the quantification of total sugars, proteins, polyphenols , moisture, pH, electrical conductivity, and mineral content. Spectroscopic (FT-IR) and chromatographic (HPLC) techniques were also employed to determine their chemical composition in detail. HPLC analysis showed a predominance of glucose and fructose in GH and DB, while DN exhibited a more balanced sugar profile with a notable sucrose content. FT-IR spectra confirmed the presence of functional groups characteristic of carbohydrates. On a practical level, these extracts were used in the preparation of two types of chocolate (solid and semi solid), which were distributed to a group of consumers along with a sensory evaluation questionnaire assessing taste, texture, and aroma. Results indicated that chocolate enriched with DB extract received the highest scores in flavor and overall acceptability, highlighting its potential as a natural and effective alternative to refined sugars in chocolate manufacturing, while also enhancing the nutritional and sensory qualities of the final product.The results of this study revealed promising prospects for scientific research and industrial application. Date sugar proved to be an effective natural and nutritious alternative in chocolate production, with the Degla Baida extract standing out for its superior quality and desirable properties, making it the best-performing variety among those studied for use in developing food products.

In this context, it would be beneficial in future research to improve extraction techniques by experimenting with advanced purification methods or enzymatic hydrolysis, with the aim of increasing the purity and stability of the extracts. It is also recommended to expand sensory studies by involving larger consumer samples and using specialized tests to more accurately assess the acceptability of products enriched with date sugar. Moreover, the functional properties of these sugars such as their glycemic impact and antioxidant capacity remain promising areas for further investigation. This could support their integration into

healthy food manufacturing strategies that respond to the growing market demand for natural products free from added refined sugars

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Annexe I

Annex 01

PH andconductivity meter (Personal photo)

Drying oven (Personal photo)

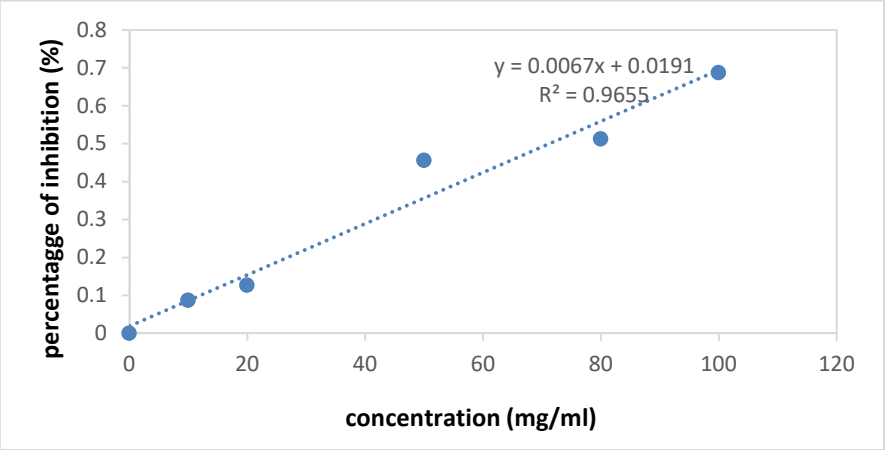
Atomic absorption spectroscopy (Personal photo)

Muffle oven (Personal photo)

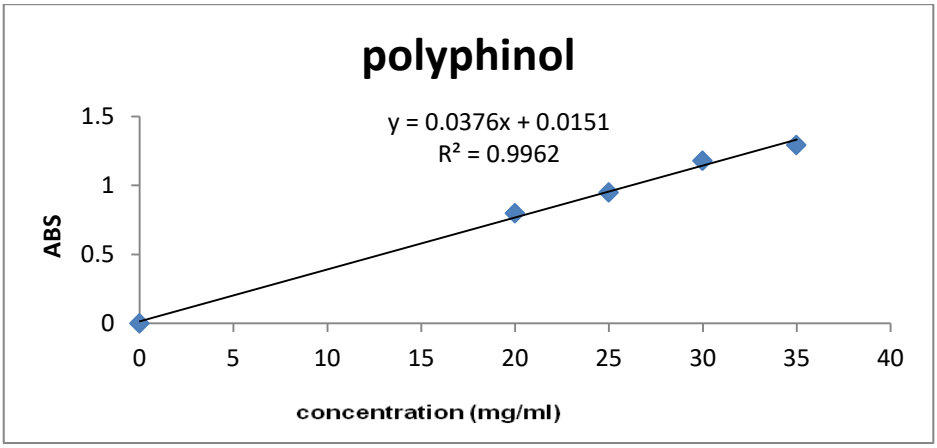
La technique HPLC (Personal photo)

FT-IR (Personal photo)

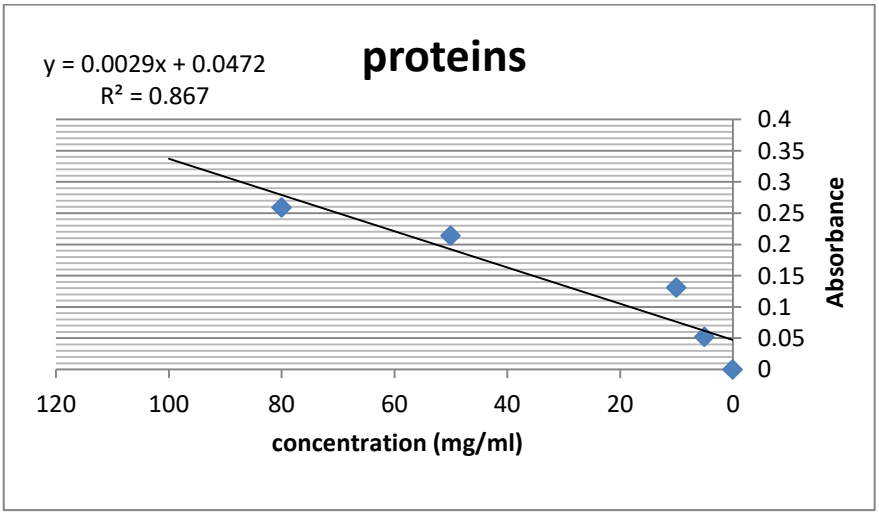
Annex 02:



Calibration Curve for Total Sugars.



Calibration Curve for polyphenol .



Calibration Curve for protein

Annexes II

دراسة الجدوى الاقتصادية

أولا: الدراسة الفنية

١. وصف المشروع:

- **اسم المشروع:**شيكولاتة داكتيليفيرا – شوكولاتةصحية محلاة بسكروزالتمر
- **نوع المشروع:** تصنيع شوكولاتة طبيعية صحية محلاة بسكروز التمر(منتجان :شوكولاتة صلبة و شكولاتة سائلة)
- **الفئة المستهدفة:** المهتمون بالغذاء الصحي ،الرياضيون،الأطفال،النباتيون،المستهلكون الباحثون عن بدائل طبيعية للسكر الصناعي
- **الموقع:**محل صغير مرخص داخل المدينة

٢. الطاقة الاستيعابية :

الطاقة الاستيعابية لمؤسسة مصغّرة تستوعب آلات و عمال و مواد خام كما يلي:

١.٢. المواد الخام:

- تمور(غرس، دقلة نور ، الدقلة البيضاء)
- مسحوق الكاكاو الخام
- زبده الكاكاو أو بدائل نباتية طبيعية
- مستخلص سكروز التمر (معصور أو مركز)
- عبوات تغليف (ورقية وصحية)
- ملونات طبيعية اختيارية (إن وجدت)

٢.٢. التجهيزات:

- خلاط كهربائي حراري (خلط الكاكاو مع سكروز التمر)
- آلة طحن التمر أو عصر التمر لاستخلاص السكريات
- قوالب معدنية أو سيليكونية لتشكيل الشكولاتة
- ثلاجة تبريد وحفظ
- سخان\مذيب زبده الكاكاو
- أدوات وزن وتعبئة يدوية
- ميزان الكتروني دقيق
- آلة تغليف يدوية أو نصف اتوماتيكية (بسيطة)

3.2. الموارد البشرية:

- صاحب المشروع

- مساعد/ة في التحضير والتعبئة
- مصمم لتغليف العلامة التجارية(اختياري)
- بائع\مسوق جزئي أو خارجي (عند الحاجة أو التوسع)

العمل يكون مدة ٥ أيام في الأسبوع. الطاقة الشهرية حوالي ١٦٠٠وحدة (صلبة +سائلة)

٣. الخدمات المقدمة :

- تصنيع شوكولاتة طبيعية خالية من السكر المضاف
- بيعب التجزئة (مباشرة أوعبرالإنترنت)
- تعبئة حسب الطلب (هدايا،مناسبات،طلباتخاصة)
- شراكات مع متاجر الأغذية الصحية والصيدليات

٤. المساحة المطلوبة تكون حوالي من ٣٠-٥٠م٢:

1.4. منطقة التحضير(fabrication) :

- تجهيز التمر
- خلط وتسخين المكونات
- تشكيل الشكولاتة في قوالب
- المساحة:١٢-١٨ **م²**

٢.٤. منطقة التعبئة والتغليف(conditionnement) :

- تغليف المنتجات
- وضعها في عبوات
- وضع الملصقات
- **المساحة:٦-١٠ م²**

3.4. منطقة التخزين:

- لتخزين المواد الخام (تمر،كاكاو،عبوات.....)
- المنتجات الجاهزة
- **المساحة:٦-٨ م²**

4.4. مكتب إداري صغير أو استقبال:

- أرشفة الفواتير
- استقبال الطلبيات

- إدارة المشروع
- **المساحة : ٤-٦م²**

5.4. ممرات وتهوية + شروط النظافة:

- ممرات كافية لتجنب التزاحم
- تهوية طبيعية أو ميكانيكية
- أرضيات قابلة للتنظيف
- توفير مغسلة يدين ومعقم
- احترام شروط السلامة الغذائية
- المساحة المتبقية: ٣-٨م٢

٥. المعدات المطلوبة :

الفئة	أمثلة للمعدات
التحضير	-مطحنة / جهاز عصر التمر / غربال كهربائي أو يدوي(grinder/mixer) / خلاط تمر
التذويب	-آلة تذويب الشوكولاتة – أو زبدة الكاكاو (Chocolat –bain marie metter) سخان حراري –خلاط حراري يدوي أو ثابت-
التشكيل	-قوالب سيلكون أو بلاستيكية غذائية-عبوات زجاجية أو بلاستيكية للشكولاتة السائلة -مجرفة توزيع-صينية تبريد
التعبئة و التغليف	آلة تغليف حراري يدوي –ميزن الكتروني دقيق –آلة طباعة الملصقات أو ملصقات جاهوة – طاولة تعبئة من ستالنس ستيل.
التخزين	-ثلاجة مناسبة لحفظ الشكولاتة -رفوف تخزين - صناديق حفظ محكمة - خزانة لحفظ المكونات الجافة
الأدوات المساعدة	- مغسلة يدين ستالنس ستيل - أدوات تنظيف و تعقيم - قفازات ،مآزر ،غطاء رأس - سلات نفايات صحية - ميزان حرارة غذائي.

ثانيا:دراسة السوق :

١.الجمهور المستهدف:

- **المهتمون بالصحة (Health-Consious)**
- **مرضى السكري تحت (اشراف طبي)**
- **المتاجر الصحية ومحلات السوبرماركت العضوية**

٢.المنافسة :

- **تحليل منتجات مثل :Pana Chocolate(خالية من السكر) ،وشكولاتة Barhi(الحلاة بالتمر)**
- **نقطة التميز:استخدام اصناف تمور محلية مميزة (دقلة نور،دقلة البيضاء،الغرس) وخلطات فريدة**
- **حجم السوق :نمو سوق الشوكولاتة الصحية عالميا بنسبة ٨% تقريبا سنويا (مصدر:Statista 2025)**

ثالثا: الدراسة المالية (تقديرية لمدة سنة

- **تكاليف تأسيسه(رأس المال الأولي):**

البند	التكلفة التقديرية (دينار جزائري)
الات التصنيع	١٥.٠٠٠.٠٠٠ دج
تراخيص +تسويق اولي	١.٨٠٠.٠٠٠ دج
التكاليف القانونية	٨٠٠.٠٠٠ دج
الاجمالي التأسيسي	١٧.٦٠٠.٠٠٠دج

- **التكاليف التشغيلية الشهرية :**

البند	التكلفة الشهرية(دج)
المواد الخام الأولية	٧٠٠.٠٠٠٠ دج
المرافق(كهرباء/ماء)	١٢٠.٠٠٠- دج
اللوجستيات والنقل	٧٠.٠٠٠ دج
الرواتب	٢.٨٠٠.٠٠٠دج
الاجمالي الشهري	١.١٧٠.٠٠٠دج

- **الإيرادات المتوقعة (شهرية):**

10 - 30 عدد العملاء اليومي

المنتج	الكمية الشهرية	متوسط السعر	الإيراد الكلي
الشكولاتة الصلبة	١٥٠-٢٠٠ كغ	٣٥.٠٠٠دج/كغ	٧.٠٠٠.٠٠٠-٥.٢٥٠.٠٠٠ دج
الشكولاتة السائلة	٢٠٠-٣٠٠زجاجة (٢٥٠مل)	٧٠.٠٠٠زجاجة/دج	-١٤.٠٠٠.٠٠٠ ٢١.٠٠٠.٠٠٠دج
الاجمالي الشهري			-١٩.٢٥٠.٠٠٠ ٢٨,٠٠٠.٠٠٠دج

- **الإيرادات السنوية :**

لدخل المالي الذي تحققه المؤسسة المصغّرة من **بيع المنتجات أو تقديم الخدمات** خلال سنة كاملة، **قبل خصم المصاريف والتكاليف**

- المواد الخام: ٨.٤٠٠,٠٠٠ دج
- الأجور: ٣.٣٦٠,٠٠٠ دج
- الإيجار والكهرباء والماء:١.٤٤٠.٠٠٠ دج
- التغليف والتسويق: ٢.٤٠٠.٠٠٠دج
- مصاريف أخرى: ١.٩٢٠.٠٠٠دج
- احتياطي طوارئ:٦٠٠.٠٠٠ دج

الإجمالي =١٨.١٢٠.٠٠٠ دج

- المصروفات التشغيلية +التأسيسية(سنة أولى 17.600.000-1.170.000=16.430.000)**دج**

BMC

BUSINESS MODEL CANVAS

Designed For:	Designed By:	Date:	Version: V1

8 KEY PARTNERS — الشركاء الرئيسيين

- مزارعو التمور المحليون
- مزودو مواد التعبئة و التغليف
- شركاء لوجستين (نقل و توزيع)
- مختبرات التحاليل الغذائية لضمان الجودة

6 KEY ACTIVITIES — الأنشطة الرئيسة

- تصنيع الشوكولاتة الصحية
- استخراج سكروز التمر
- التغليف و التوزيع
- التسويق وبناء الهوية البصرية
- البحث والتطوير لانتاج نكهات جديدة
- البحث والتطوير

7 KEY RESOURCES — الموراد الرئيسية

- الات الانتاج (لصناعة الشوكولاتة واستخراج السكروز)
- المواد الخام :تمر،كاكاو،مكسرات ،تغليف
- فريق العمل: فني انتاج،مسوقين،مندوبي مبيعات
- منصة تسويق الكترونية

1 VALUE PROPOSITIONS — القيمة المقدمة

- منتج فريد يجمع بين الطعم اللذيذ والفوائد الصحية
- اعتماد سكر التمر كمُحلِّ طبيعي خالٍ من المواد الصناعية.
- تغليف جذاب مع معلومات غذائية واضحة تعزز وعي المستهلك
- منتج محلي يساهم في تثمين التمور الجزائرية.

3 CUSTOMER RELATIONSHIP — علاقات العملاء

- حملات توعوية رقمية حول فوائد المنتج
- عينات مجانية وتجربة المنتج في المعارض
- تواصل مباشر وعبر مواقع التواصل الاجتماعي

4 CHANNELS — قنوات التوزيع

- مندوبو مبيعات المحلات والصيدليات
- البيع عبر وسائل التواصل الاجتماعي والمواقع الالكتروني
- اكشاك تجريبية في المعارض والاسواق المحلية
- اتفاقيات مع متاجر البيع بالتجزئة

2 CUSTOMER SEGMENTS — الشرائح المستهدفة

- مرضى السكري والأشخاص المهتمون بالصحة
- الرياضيون
- محلات المنتجات العضوية والصحية
- الأسواق الراقية ومحلات الهدايا
- المتاجر الإلكترونية

9 COST STRUCTURE — التكاليف

- تكاليف تأسيسية: معدات تصنيع الشوكولاتة، آلة استخلاص سكروز التمر، التغليف 21.000.000 دج
- تكاليف تشغيلية :مواد خام (تمر ،كاكاو،مكسرات....) اجور العمال، التسويق، النقل23.640.000 دج

5 REVENUE STREAM — الارادات

- مبيعات الشوكولاتة الصحية
- عقود التوزيع بالجملة
- علب الهدايا و العروض الموسمية تقصد انتاج علب هدايا

Phoenixa product prototype


Phœnixa
Chocolate dactylifera
شكولاطة فاخرة بسكر العرس
Natural 100%
65g
Phœnixa
Chocolate dactylifera
Natural 100%
150g
Phœnixa
Chocolate dactylifera
شكولاطة فاخرة بدقلة البيضاء
Natural 100%
65g


Phœnixa
شكولاطة فاخرة بدقلة نور
Natural 100%
Phœnixa
شكولاطة فاخرة بدقلة البيضاء
Natural 100%
Phœnixa
شكولاطة فاخرة بسكر العرس
Natural 100%