الجمهورية الجزائرية الديمقراطية الشعبية
République Algérienne Démocratique et Populaire
Democratic and Popular Republic of Algeria
Ministère de l'Enseignement Superieur et de la Recherche Scientifique
Ministry of Higher Education and Scientific Research
وزارة التعليم العالي و البحث العلمـي
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Order number: 056

Field: The Natural and Life Sciences

Sector: Veterinary sciences

Final Thesis

For the attainment of **Doctor of Veterinary Science degree**

Study on dietary supplementation in dairy cows: OLIVE POMACE

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Academic year 2023-2024

Acknowledgements

This work is the culmination of a lot of determination and consistency.

My gratitude goes first to the Creator of the universe who endowed us with intelligence.

*My thanks go to my supervisor **Mr. SOUAMES** for his supervision, his guidance, his advice and the patience he showed me to allow me to carry out this work successfully.*

My thanks also go to the teachers who gave me the honor of being part of the jury:

*Mrs. **BERRAMA** for her availability to chair the jury;*

*Mrs. **AOUANE** for agreeing to judge the work;*

*I express my deep thanks to Miss **MERAD** the doctoral student for her help.*

Finally, I thank everyone who helped me directly or indirectly in the development of this work.

Dedications

I dedicate this work to **my mother**, may God grant her the highest degrees of paradise, Thank you for being the kind, warm, beautiful and generous mother that you are. It has always been an immense honor for me to be your son. And today I humbly pray that you're taking pride in being my mother as well.

To **my father**, who has been a solid pillar and a constant example of motivation for me, I thank him for his unconditional support, his generosity, his trust and his dedication to me, which were determining factors in the success of this work.

To my two brothers, **Samir** and **Zouhir**, whom I know I can always and forever count on.

from other mothers, the boys of **Valhala**, (**Akram**, **Ramy**, **Raid**, **Ismail**, **Salah** and **Nadir**) who stood by my side on the good times as well as the bad ones and has been like a second family to me, you are legends.

To my beautiful girls, **Sabrina** the most beautiful angel, the **QUEEN SHIRAZ** who carries grace and elegance, **Sarah** the CUTEST person in the universe and **Houda** who always brings joy and happiness with her, those who believed in me and supported me through everything and anything. You truly are a gift from God.

To those with whom I haven't spent much time but truly cherish: the charming **Oumhani**, **Marwa**, **Asma**, **Islem**, and **Reda**.

To my friends whom I consider my brothers: **Anes**, **Anis**, **Raouf**, **Amine**, **Noureddine**.

To all my colleagues from The Higher Veterinary School.

List of abbreviations

DM: dry matter

NDF: neutral detergent fiber

ADF: acid detergent fiber

ADL: acid detergent lignin

ADC: apparent digestibility coefficients

OM: organic matter

CP: crude protein

CF: crude fiber

OP: olive pomace

VFA: volatile fatty acid

NEL: net energy of lactating

DNM: degestible nitrogeneous matter

CC: crude cellulose

HC: hemocellulose

CELL: cellulose

TNM: total nitrogeneous matter

NEP: net energy of meat prodction

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Abstract

This study focused on evaluating the potential of olive pomace as a feed component for ruminants, with particular emphasis on its effects on dairy cow performance. The work aimed to assess the impact of incorporating olive pomace into dairy cattle diets on milk production and quality.

To achieve this objective, we conducted a comprehensive review of various research studies, comparing their findings to draw meaningful conclusions. The investigation covered several key aspects. We explored the characteristics of olive pomace, including its chemical composition, nutritional value, and potential limitations as a feed ingredient. We looked at how different levels of olive pomace inclusion in diets influenced milk yield, composition, and quality in dairy cows.

The study also investigated the potential environmental benefits of utilizing olive pomace in animal feed, considering its status as an agricultural waste product. Additionally, we evaluated the economic viability of using olive pomace in dairy cow diets, taking into account factors such as feed costs and potential impacts on milk production value.

This multifaceted approach allowed us to provide a thorough evaluation of olive pomace as an alternative feed resource for dairy cattle, considering both its practical applications in animal nutrition and its broader implications for sustainable agriculture and waste management.

Keywords : Olive pomace, Dairy cow performance, Milk production, supplementation Nutritional value.

Résumé

Cette étude a porté sur l'évaluation du potentiel des grignons d'olives en tant que composant alimentaire pour les ruminants, avec un accent particulier sur ses effets sur les performances des vaches laitières. Le travail visait à évaluer l'impact de l'incorporation des grignons d'olives dans les régimes alimentaires des bovins laitiers sur la production et la qualité du lait.

Pour atteindre cet objectif, nous avons mené une revue complète de diverses études de recherche, comparant leurs résultats pour en tirer des conclusions significatives. L'enquête a couvert plusieurs aspects clés. Nous avons exploré les caractéristiques des grignons d'olives, y compris leur composition chimique, leur valeur nutritionnelle et leurs limitations potentielles en tant qu'ingrédient alimentaire. Nous avons examiné comment différents niveaux d'inclusion des grignons d'olives dans les régimes alimentaires influencent le rendement, la composition et la qualité du lait chez les vaches laitières.

L'étude a également examiné les avantages environnementaux potentiels de l'utilisation des grignons d'olives dans l'alimentation animale, compte tenu de leur statut actuel de déchet agricole. De plus, nous avons évalué la viabilité économique de l'utilisation des grignons d'olives dans les régimes alimentaires des vaches laitières, en prenant en compte des facteurs tels que les coûts des aliments et les impacts potentiels sur la valeur de la production laitière.

Cette approche multifacette nous a permis de fournir une évaluation complète des grignons d'olives en tant que ressource alimentaire alternative pour les bovins laitiers, en considérant à la fois ses applications pratiques en nutrition animale et ses implications plus larges pour l'agriculture durable et la gestion des déchets.

Keywords : grignon d’olive, performance des vaches laitieres, production de lait, supplémentation, valeur nutritionelle.

الملخص

ركزت هذه الدراسة على تقييم إمكانيات تفل الزيتون كمكون غذائي للمجترات، مع التركيز بشكل خاص على تأثيره على أداء الأبقار الحلوب. هدفت الدراسة إلى تقييم تأثير إدماج تفل الزيتون في حميات الأبقار الحلوب على إنتاج وجودة الحليب.

لتحقيق هذا الهدف، قمنا بمراجعة شاملة لمختلف الدراسات البحثية، وقارنا نتائجها لاستخلاص استنتاجات ذات مغزى. غطت الدراسة عدة جوانب رئيسية. استكشفنا خصائص تفل الزيتون، بما في ذلك تركيبه الكيميائي، قيمته الغذائية، والقيود المحتملة كمكون غذائي. كما فحصنا كيف تؤثر مستويات مختلفة من إدماج تفل الزيتون في الحميات الغذائية على إنتاجية، تركيب، وجودة الحليب في الأبقار الحلوب.

كما بحثت الدراسة الفوائد البيئية المحتملة لاستخدام تفل الزيتون في تغذية الحيوانات، بالنظر إلى وضعه الحالي كمنتج نفايات زراعية. بالإضافة إلى ذلك، قمنا بتقييم الجدوى الاقتصادية لاستخدام تفل الزيتون في حميات الأبقار الحلوب، مع مراعاة عوامل مثل تكاليف الأعلاف والتأثيرات المحتملة على قيمة إنتاج الحليب.

سمحت لنا هذه المقاربة المتعددة الجوانب بتقديم تقييم شامل لتفل الزيتون كمورد غذائي بديل للأبقار الحلوب، مع مراعاة تطبيقاته العملية في تغذية الحيوانات وآثاره الأوسع على الزراعة المستدامة وإدارة النفايات.

كلمات مفتاحية: ثفل الزيتون، أداء الأبقار الحلوب، إنتاج الحليب، المكملات الغذائية، القيمة الغذائية.

Contents

Introduction

Feed represents 60 to 80% of the total production costs for cattle **(Rejeb Gharbi et *al*., 2007)**. The limitation of forage resources in Algeria, whose main limiting factors are represented by low forage potential and highly unpredictable bioclimatic conditions, is primarily responsible for the heavy dependence on imported feeds used in concentrate production (soybean meal, barley, and corn). The continuously growing imports of these feeds (4 million tons of corn and 1.25 million tons of soybean for 1.2 billion dollars annually, **(ONAB, 2021)** and the rise in their global prices (especially with the Russian-Ukrainian crisis) have led to an exponential increase in production costs of animal products (milk and meat).

Improving the level of adequacy between the nutritional needs of dairy cattle and local forage availability necessarily involves searching for alternative forage resources and valorizing agricultural by-products. Among local agricultural by-products, olive residues in the form of pomace and olive mill wastewater are two materials that are difficult to degrade, unfortunately discharged into nature, and cause serious environmental problems. Thus, 80% of olive oil by-products that could be valorized in livestock feed are lost, a valorization that could have a positive impact on the national economy.

Algeria is among the main olive oil-producing countries with 89,500 tons in 2020, ranking the country 8th worldwide. For every ton of oil recovered, about 3 tons of waste (pomace and olive mill wastewater) are produced. Unfortunately, these olive industry wastes remain largely unexploited and are often stored and released into nature, yet these residues are toxic to the environment and can contaminate soils, groundwater, and waterways due to their acidity, salinity, and especially their polyphenol content **(Benyahia et *al*, 2003)**. However, these polyphenols are gaining increasing importance, particularly due to their role as natural antioxidants and antimicrobials, generating growing interest in the feed industry.

In Algeria, olive pomace represents a considerable potential for forage resources but is insufficiently exploited. Despite chemical, physical, and nutritional characteristics that classify them among poor quality forages, some recent research has shown that olive pomace can substitute at relatively high rates for imported ingredients in ruminant rations. Research work has shown that incorporating olive pomace (5.61%) into the diet could represent a beneficial supplement for dairy cattle **(Zilio et *al*., 2014)**. Dietary supplementation with olive pomace seems to be useful for improving the quality of dairy products **(Castellani et *al*., 2017)**. Pomace can also be very useful in times of scarcity (in the form of pomace silage) if considered in terms of maintenance or even preservation and not solely in terms of production **(Rejeb Gharbi et *al*, 2011)**. In most olive-producing countries, olive by-products (pomace and olive mill wastewater) are valorized and bring enormous benefits.

I. Milk production

Milk production

Milk is a food of great nutritional value. It is an inexpensive source of high-quality proteins and dietary calcium. This richness gives milk the strategic place it occupies in the diet of the vast majority of the world's population, and self-sufficiency in this essential product is a significant indicator for judging the economic "good health" of a given country across different regions of the world. In this context, it must be noted that Algeria is still unable to satisfy the ever-increasing needs of its population for locally produced milk, primarily from cattle (predominantly) and other species (sheep, goats, and camels), which represent about 20 to 25% of total production **(KAOUCHE-ADJLANE,2015).**

The dairy industry represents a strategic sector in Algerian agricultural policy, particularly for its versatile role as a provider of animal proteins (milk and meat) and a source of income. Indeed, milk contributes an average of 16% to the daily protein intake, while other animal products such as meat (red and white) and eggs account for only 10.24% **(DAOUDI A., BOUZID A., 2020)**. Algeria is the largest consumer of milk in the Maghreb region, with an average consumption of 147 liters per person per year in 2015 **(O.N.I.L., 2017)**. National production reached nearly 3.6 billion liters in 2019, of which 2.7 billion liters were cow's milk, representing more than 75% of the total national production. The remainder of milk production is provided by sheep and goats **(M.A.D.R., 2019. M.A.D.R., 2016).**

The milk production and reproduction performances of imported breeds (Holstein Friesian and Red Holstein) remain inferior compared to their production potential in their countries of origin **(KAOUCHE-ADJLANE S., GHOUZLANE F., MATI A., 2015)**. The annual productivity of 295 dairy cows in the North-central region of Algeria ranges between 3053.4 and 6551.5 kg/cow, with an average of about 4400 kg **(KAOUCHE S., MATI A., 2017)**, while the yields of 822 dairy cows in the mountainous regions of the Medea wilaya were estimated at 4884 kg/cow **(KAOUCHE-ADJLANE S., BOUDINA M., GHEZALI S., 2012)**. Milk production remains insufficient compared to the demand for milk, which is estimated at almost 6 billion liters for a population of about 40 million inhabitants **(O.N.I.L., 2019).**

I.1. Cattle and dairy cow populations

In Algeria, sheep farming is predominant. It represents 79% of the total livestock population. It is followed by goat farming with a rate of about 14%, then cattle farming which represents only about 6% of the total livestock, of which 51% are dairy cows. The camel population represents 1% of the total livestock **(M.A.D.R., 2017)**. The cattle population has recorded a decrease in recent years (Figure 1). It was estimated in 2015 at nearly 2.2 million heads. This number experienced consecutive drops of 3.2% and 8.9% between the 2015-2016 and 2016-2017 campaigns respectively, and 2% between 2018 and 2019 **(F.A.O Stat., 2020).**

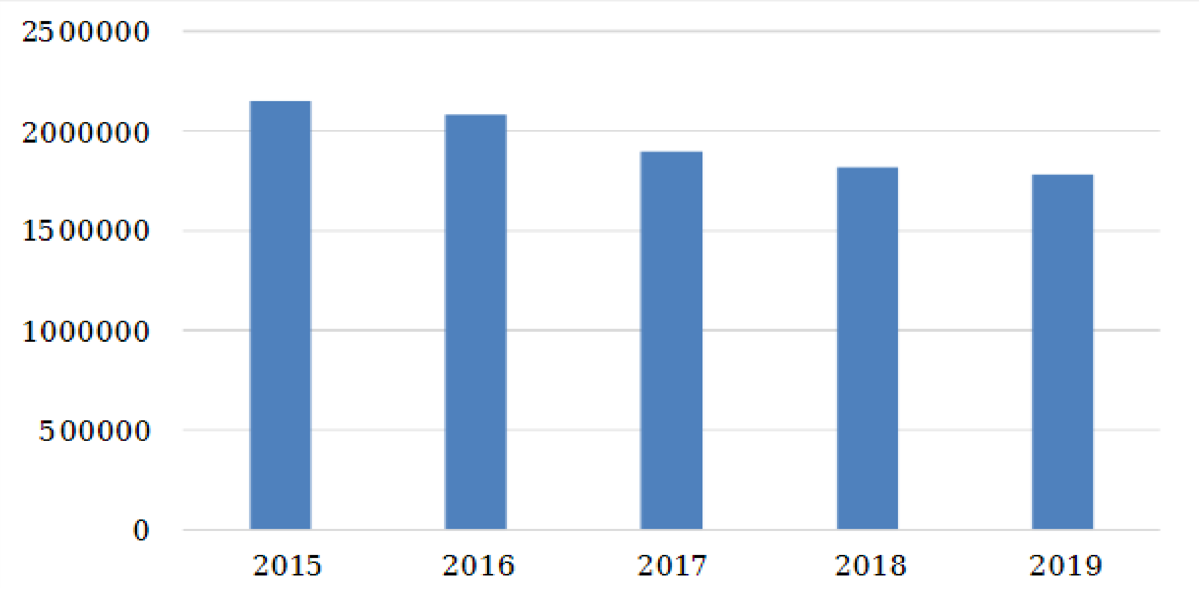

Figure 1 : Evolution of cattle populations in Algeria **(F.A.O STAT., 2020)**.

I.2. Evolution of Dairy Production in Algeria

The milk production collected during the year 2012 was 756 million liters, of which nearly 160 million liters were from the 14 branches of the public dairy sector. Nearly 80% of the collected milk is processed through the private sector's transformation circuits, numbering 139 units, under agreement with ONIL, of which about ten fully utilize raw milk and benefit from the integration premium of 6 DA/l **(ITLEY, 2013)**.

The total milk production in Algeria reached 2.92 billion liters in 2011, of which 73% was cow's milk (Figure 1). In 2009, production reached 2.39 billion liters, of which 73% was cow's milk, 16% was sheep's milk, 9% was goat's milk, and 2% was camel's milk.

Depending on the year, cow's milk production accounts for 70 to 75% of national milk production. Moreover, the majority of collected milk is cow's milk.

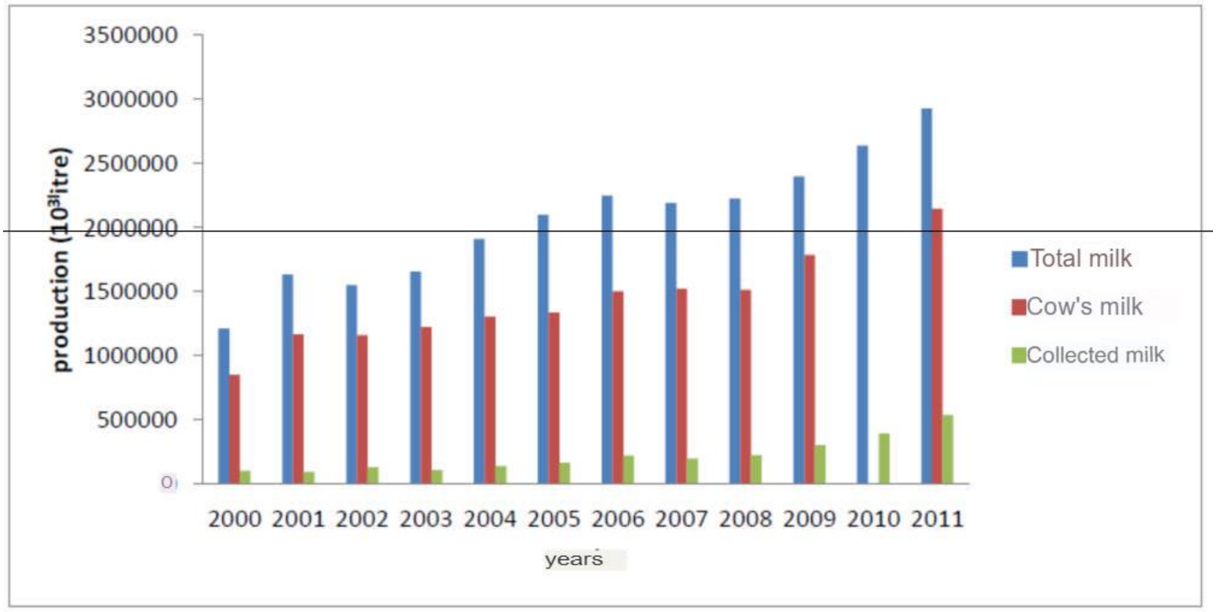

Figure 2 : Evolution of milk production, cow's milk production, collected milk **(BRABEZ, 2011).**

On a territorial level, milk production is concentrated in the wilayas of Setif (7.9% of the national total in 2011), followed by the wilaya of Sidi Bel Abbes (5.9%), the wilaya of Skikda (3.9%), Tizi-Ouzou (3.4%), Medea (3.4%), Mila (3.2%), Mostaganem (3.15%), and finally Souk Ahras and Constantine with 3.1% each. These nine wilayas together account for almost 38.17% of Algerian production **(BRABEZ, 2011).**

I.3. Milk Consumption

Algerians consume more milk than the annual global average set by the FAO at 90 liters per person. Indeed, this consumption was estimated at 147 liters in 2015. Thus, the Algerian citizen consumes about 57 liters per year more. However, the annual milk availability reached 121 kg per person, while it was 52 kg in Morocco, 42 kg in Egypt and Jordan, and 111 kg in Tunisia **(DAOUDI, BOUZID, 2020).**

Furthermore, in 2019, the annual milk consumption in Algeria was 5.9 billion liters, of which 3.6 billion were produced locally, representing a self-sufficiency rate of 61%. The deficit of about 2.3 billion liters is filled by imports. The main sources of these imports are Holland and Uruguay **(O.N.I.L., 2019).**

I.4. Constraints on Dairy Sector Development

Livestock farming is very important in the development of countries, especially for societies that are large consumers of animal proteins, particularly milk, like Algeria. However, the development of the dairy production sector first requires highlighting the obstacles that hinder its growth in order to increase production. In Algeria, dairy cattle farming continues to be subject to a set of technical, socio-economic, structural, and organizational constraints that impede its development **(KAOUCHE et al., 2015).**

I.4.1. Technical Constraints

Feed constitutes a major constraint for dairy cattle farming **(KAOUCHE et al., 2015).** Forage crops are far from satisfying the nutritional needs of the national herd in terms of quantity and quality. The exotic cows that have been introduced for greater efficiency in dairy production are still expensive and more difficult to manage. This is related to their lack of adaptation to the country's climatic conditions and inadequate management practices at the farm level. The production system continues to suffer from the limited technical skills of farmers (due to a lack of supervision and extension channels) (**KAOUCHEet al., 2012).** Indeed, little-known, farming practices are often wrongly considered underperforming and unsuitable **(KAOUCHE et al., 2015).** The quantities of milk produced by our farms are progressing year by year, but they have remained below expected results. This situation is exacerbated by the near absence of milk recording, which can only hinder the evaluation of the actual performance of dairy farms in their diversity.

I.4.2. Socio-economic Constraints

The high cost of feed also heavily penalizes the farmer's profession since a bale of oat hay is paid at 1000 Da and straw at 700 Da. State intervention has mainly focused on expanding the market through support for consumer milk prices, making it difficult to cover production costs. Today, farmers finding the solution in the massive use of concentrated feeds in the rations distributed to dairy cows encounter abundant difficulties in ensuring the profitability and sustainability of their farms **(KAOUCHE et al., 2015).**

II. Alimentation and alimentary supplementation

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II.1. Alimentation

The objective of nutrition is to provide the nutritional elements necessary to satisfy all needs. For a dairy cow, these needs are represented by maintenance requirements, production needs, gestation requirements, and, in the case of a first-calf heifer, growth needs. Meeting these requirements allows for optimal production if it is done while respecting the general physiology of the ruminant and particularly that of the lactating cow.

In Algeria, livestock farming is an important indicator to some extent in the economy, as it constitutes a source that covers part of the national needs for animal proteins and the development of the workforce in rural areas **(MOUFFOK, 2007)**. The dairy sector in Algeria is in a critical phase, faced with insufficient local production, aggravated by a very low collection rate and an increase in the prices of raw materials on international markets **(BELHADIA ET AL., 2009).** Feeding cows is becoming an ambition for breeders, both technically (quality, quantity, availability, and feeding method) and economically (cost and milk yield). The limiting factor of feed is often shown as the main technical constraint of livestock farming **(SRAIRI ET AL., 2007).** The diet affects the quantity and quality of milk produced. It is therefore necessary to master the production cycle and the needs of the animal in order to adapt its food intake **(DROGOL ET AL., 2004)**. The aim of our study is to analyze the feed rations distributed by dairy cattle breeders in the M'Sila region, to critique these rations from a quantitative and qualitative point of view, and to propose standard rations based on the real needs of cows and the availability of feed for the breeder.

II.2. The composition of feeds

Foods provided to cattle are composed of water and various nutrients: carbohydrates, lipids, nitrogenous substances, vitamins, and minerals, as well as substances completely devoid of nutritional value, such as lignin.

When food is placed in an oven, the water contained in the food evaporates, and a dry residue remains, called dry matter (DM). All foods contain a certain fraction of DM. For example, the DM content of grass varies around 20%, while that of hay and cereals is around 85% and 90%, respectively. Dry matter (DM) consists of, on one hand, organic matter, cell wall carbohydrates (commonly called 'fibers': cellulose, hemicellulose, and pectins) and cytoplasmic carbohydrates (starch and soluble sugars), lignin, lipids, nitrogenous substances, and fat-soluble and water-soluble vitamins, and on the other hand, mineral matter, macro-elements and trace elements **(CUVELIER ET AL. 2005)** (figure 3).

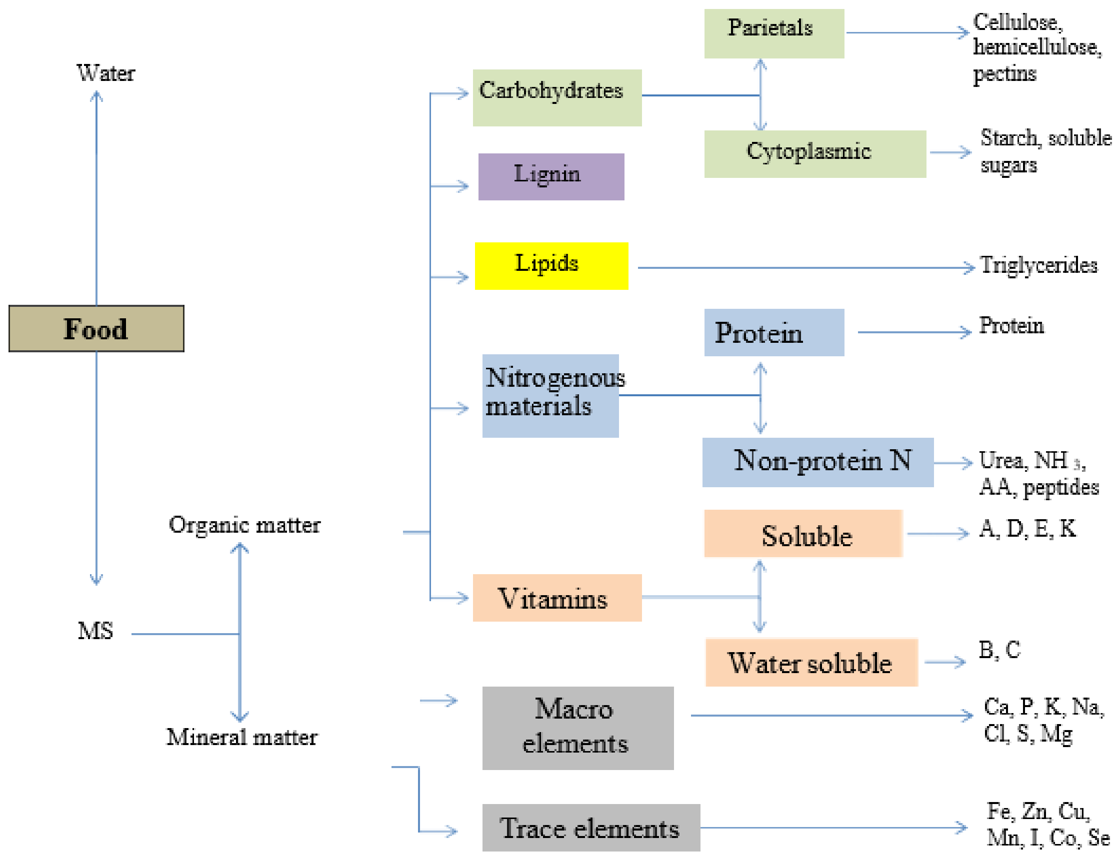

Figure 3 : Feed composition **(based on BROCARD Et Al, 2010).**

II.2.1. Types of cow feeding

Due to the presence of a varied microbial population in the rumen, ruminants can utilize fiber-rich foods, such as forages, those other animals as monogastrics cannot digest.

II.2.1.1. Forage

Forage plants generally encompass a very large number of species, including legumes, grasses, and others. This fact results from the nature of what forage plants are, whose general definition includes all species whose vegetative parts are used for animal feed (**PELLERIN ET AL, 1989)**. From a nutritional point of view, forage is characterized by its nutritional value (energy value, nitrogen value, mineral content, vitamins, etc.) **(JARRIGE ET AL, 1988).**

Forages are foods of plant origin rich in "fibers" (cellulose and lignin), their crude cellulose content in dry matter exceeds 15%, with a very abundant fibrous composite (greater than approximately 150 fibers per kg of DM). **(JARRIGE ET AL, 1988).**

II.2.1.1.1. Green forages

Green forages include grasses. Grazed grass is a forage of high nutritional value, inexpensive to produce, and which can constitute, as we will see, the sole food in the ration of dairy cows **(CUVELIE; DUFRANCE, 2005).**

➢ Barley: Hordeum Vulgare

Belongs to the Gramineae family, its Latin name is (Hordeum Vulgare). It's a very hardy species and can therefore be cultivated in marginal areas with more or less poor soil, where wheat cannot give satisfactory results. Moreover, this species is quite interesting given its tolerance to salt and drought **(BOUZIDI, 1979).** The grain, hay, and straw are used for animal feed. The interest in barley lies in the fact that it can provide good winter fodder and at the same time produce grain on regrowth after topping **(JANATI, 1990)**.

➢ Forage Sorghum: S. Vulgare

Constitutes the Sorghum genus of the Gramineae family, belonging to the S. Vulgare species. Forage sorghum is a forage species well adapted to oases and very productive as it can be grown as a catch crop from March-April to October **(JANATI, 1990).** Sorghum has a high starch content (70% DM), a significant proportion of fat (about 3.3% DM) and is richer in protein than corn (11.4% DM) **(FAO, 1990)**.

➢ Corn: Zea Mays

Belongs to the Gramineae family, a fairly tall cereal, monoecious species with cross-pollination widely cultivated for its grain used in human and animal nutrition, and as fodder in whole plant form (stem, leaves, ears) consumed by animals **(BERNARD, 1999).** According to **(HABBAS, 2009)**, corn has a high energy and nitrogen concentration, thus a good nutritional value but is poor in cellulose and water. It can provide:

- Energy: 3200 Kcal
- Crude protein: 8-9% of DM/Kg

- Fat: 4.5% of DM/Kg
- Cellulose: 2.20% of DM/Kg **(FOURNIER, A et al, 2009).**

➢ Protein crops and crucifers

Fava bean and pea plants have a constant digestibility from flowering onwards, similar to that of corn (fava bean 71%, pea 73%) but are much richer in nitrogenous matter (about 15% to 18%) and are better ingested. They produce less (around 6 and 8 tons of DM/ha), but enrich the soil with nitrogen and can be harvested at the consistent grain stage. **(CUVELI; DUEFRANCE, 2005).**

II.2.1.1.2. Dry forages

Dry forages include hay, alfalfa, and straw, which can notably be valorized in the form of hay, as also seen here. These are foods that have in common a high DM (Dry Matter) content, greater than or equal to 85%, rich in fibers and tissues from the exploitation of grasses at fairly advanced stages, i.e., either at heading for hay or maturation for straw. **(CUVELI; DUEFRANCE, 2005).**

- Hay

Hay is a food resulting from herbaceous dehydration where the water content drops from 80 to 15%. Good hay is therefore characterized by a high DM content, around 85 to 90%. From the point of view of chemical composition and nutritional value, hay is characterized by a variable crude protein content, rather high when it comes to legume hay or good quality hay. The energy content of hay is generally lower than that of grass silage. **(BOUREZOUR; MAKHLOUF, 1989).**

- Straw

Straw consists of the stems and rachis of threshed ears of cereals. The nutritional value of straw is always low, which explains its use as bedding or as ballast feed. Straw is indeed characterized by a very high fiber content, with a high lignification rate of cellulose/hemicellulose, a very low content of soluble sugars and proteins, as well as low energy content. However, straw is a feed that presents certain interest, it stimulates chewing, rumination. It also slows down fermentations, which helps to fight against rumen acidosis when administering rations very rich in fermentable carbohydrates. **(CUVELIE; DUEFRANCE, 2005).**

- Dry alfalfa

Alfalfa is a forage legume known for its high content of proteins, good quality fibers, vitamins, and pigments. It is mainly used in the form of hay or dehydrated pellets. It does not contain anti-nutritional factors for ruminants, but its use in grazing may require some caution due to the risk of bloat. Alfalfa is essential in the diet of ruminants, particularly for dairy cows, but it is also used for small ruminants and horses **(RITA, MELIS ET AL, 2017).**

II.2.1.2. Silages

Silage is a system for preserving forages through anaerobic fermentation in a silo: bacteria transform soluble sugars into organic acids (mainly lactic acid and acetic acid) which lower the pH in the silage. It then becomes stable. As the soluble sugars are consumed by bacteria, silage is characterized by an almost zero content of soluble sugars. The main foods suitable for ensiling are grass, whole plant corn (or high-moisture grain), beet derivatives (mainly wet pulp and pressed pulp), and immature cereals. Legume silage is also sometimes encountered, more specifically whole plant pea silage. **(WOLTER ET AL., 2013)**

Silage is divided into 04 different types which are:

- Corn silage
- Grass silage
- Wet pulp silage and pressed pulp silage
- Immature cereals.

Figure 4 : Grass silage (**WOLTER et al., 2013)**.

Figure 5 : Corn silage **(WOLTER et al., 2013)**

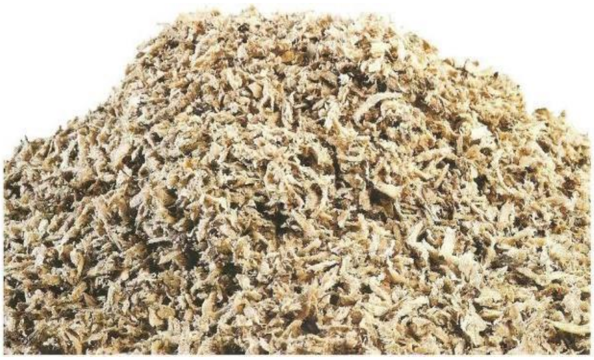

Figure 6 : L'ensilage de pulpes humides **(WOLTER et al, 2013)**.

Figure 7: Immature cereals **(WOLTER et al, 2013)**.

II.3. Supplementation

Animal production in Algeria is facing a difficult situation: on one hand, there is an increase in demand for animal proteins, and on the other hand, there is a forage supply affected by an unstable climate, a small area dedicated to cultivated forage (628,889 ha, which represents 7.64% of the Utilized Agricultural Area, Ministry of Agriculture, 2005), and poorly organized management. Indeed, forage resources in Algeria are limited to cereal straw, poor quality hay, some cultivated forages, and especially steppe rangelands (20 million ha), not to mention stubble fields (3 million ha) and fallow lands grazed by animals (2 million ha) **(GREDAAL, 2003).** Faced with this situation, our livestock is often undernourished, especially during periods of scarcity, where high mortality rates are observed and where we would be forced to shift our reasoning from the term "production" to "maintenance" or even "preservation" **(CHERMITI, 2002).**

II.3.1. Agro-industrial by-products

To preserve livestock during periods of food crisis, the use of agro-industrial by-products is of great interest, even if only partial. Cataloguing these by-products, quantifying them, locating them, determining their nutritional value, and defining standard rations to be popularized is a task of national interest that can have beneficial consequences on animal production.

These by-products are primarily represented by citrus pulp, molasses, poultry droppings, urea, date packaging waste, olive pomace, whey, grape marc, tomato waste, corn gluten, brewery spent grains... (Table 1). Some of these by-products (olive pomace and grape marc) are poor from a nutritional point of view **(MOLINA AND AGUILERA, 1991, NEFZAOUI, 1991)** but should not be neglected as they can be improved by chemical treatments (treatment with sodium hydroxide, ammonia or urea) **(O'DONOVAN, 1983, MERABET, 1984, SANSOUCY, 1984).**

Table 1: Main Algerian agro-industrial by-products **(BOUHAROUD, 2007)**.

By product	Quantity of raw products in ton/year	Availability periods
Citrus pulp	1900	January to March
Tomato waste	1840	June to september
molasses	8804	All year
Waste dates	230	Autumn
Olive pomace	51105	November to february
Corn gluten	1400	All year
Brewery spent grain	230	All year
Dehydrated poultry manure	1266000	All year

The use of these by-products in animal feed has two main benefits:

- The first is economic, primarily concerning farmers since the majority of agro-industrial by-products are given to them for free. This reduces feed costs **(BOUHAROUD, 2007)**
- The second is ecological, as it helps avoid the accumulation and consequences of these food industry wastes in landfills **(BOUHAROUD, 2007)**

II.3.1.1. By-products of the cereal industry

The industrial transformation of soft wheat into white flour generates three by-products that are generally marketed: bran, coarse remilling, and white remilling. Two other by-products are low-grade flour and germs **(KELLOU.R., 2008).** These are dry foods, less rich in nitrogenous matter, rich in starch, and low in fiber content **(CUVELIER; DUFRANCE, 2005).**

II.3.1.2. By-products of the olive oil industry

The olive oil industry, in addition to its main product (virgin olive oil), leaves two residues: one liquid (olive mill wastewater) and one solid (pomace) (**NEFZAOUI, 1991**). Pomace is rich in cellulose and poor in nitrogenous matter **(INRA, 1988).**

II.3.1.3. By-products of the date industry

This is a traditional method for livestock feed. The date palm is used for human consumption, but it also offers a wide range of by-products used for livestock feed, namely date waste, pedicels, and dry palms. **(CHEHMA et al., 2001).**

II.3.1.4. Citrus by-products: citrus pulp

Citrus pulp can be defined as the solid residue that remains after the fresh fruit is pressed for juice extraction **(GOHL, 1981).** The energy value of the pulp is very high. On the other hand, its nitrogen value is very low. It is considered a very energy-rich food **(INRA, 2007).**

II.3.1.5. By-products of the sugar industry

Molasses is the waste from sugar manufacturing units; it's a by-product used in animal feed in different forms and aspects. It is commonly used in ruminant feed mixed with straw or other cellulosic foods such as bran, as a binder in complete rations, or to enhance less palatable foods (hay, straw). Molasses, thanks to its sugars and salts, constitute a food whose flavor and odor stimulate appetite and promote digestion. Molasses is a food of very high energy value. Due to its richness in fermentable carbohydrates (60 to 65% of soluble carbohydrates, the majority of which is represented by sucrose), it is poor in Ca, P, and Vit B, but rich in Na and K. **(CHEREF, 1995).** The use of molasses is economical as it does not require significant investment; its cost is low, and it enriches poor foods **(HAMMOUCHE, 2000)**

III. Generalities about olive pomace

III. Generalities about olive pomace

According to **BOUCHERBA (2014),** a by-product is a residual product that appears during the manufacturing, transformation, or distribution process of a finished product. It may be used directly, or may constitute an ingredient in another production process for the manufacture of another finished product.

Among the wide range of by-products, we have chosen to study olive pomace, the by-product of olive oil extraction. Despite their chemical, physical, and nutritional characteristics that classify them as low-quality fodder, some research has shown that olive pomace can be substituted at relatively high rates for imported ingredients in livestock rations.

III.1. Extraction of olive pomace

Although the olive tree can be found on four continents, around 95% of the world's olive oil production comes from the Mediterranean basin. The olive tree is considered a characteristic species of the Mediterranean region. It is found mainly between the 25th and 45th degrees of altitude, in both the northern and southern hemispheres, even in America (California, Mexico, Brazil, Argentina, Chile), Australia, and even China (**BENHAYOUN AND LAZZIRI, 2007**).

According to figures provided by the international body responsible for monitoring olive oil production, Algeria produced 66.700 tonnes of olive oil in the 2016-2017 season, compared with 80,000 tonnes in 2017-2018, ranking 9th in the world.

In addition to its main product, oil (virgin olive oil and pomace oil), the olive industry leaves two residues: one liquid (margines) and one solid (pomace). Furthermore, by adopting an average of 35% crude pomace (with a moisture content of 25-27%), which, after exhaustion (extraction of residual oil) by solvent, yields 25-26 kg of exhausted pomace (with a 15% moisture content), 13-14 kg of shell and a further 12-13 kg of pulp (with a moisture content of 5-8%) (**NEFZAOUI,1991**).

Compared to processed olives, according to NEFZAOUI (1991), world production of pomace is around 2.9 million tonnes. Knowing that on average, 100 kg of processed olives generate 100 liters of margines, world margine production would be 8.4 million cubic meters.

Recycling these residues has become a necessity in order to avoid increasingly serious pollution.

III.2. Processes of extraction of olive pomace

After the harvest, which takes place between October and December, the olives are crushed. Crushed olives or turtles are either pressed or centrifuged to extract a liquid phase containing the oil. The remaining solid-phase pomace, with a weight of about one-third, is a waste (**COI, 1989**). The liquid phase is fractioned between the virgin oil and a liquid waste, the margin.

Pomace are composed of two parts, the solid residue of the flesh of the olive or pulp, which represents 40% by weight, and its core or shell, which represents the remaining 60 % (**AZRI, OBAY,MEDHIOUB, 1989**). This is an average composition that does not take into account the solid/liquid separation technique used, such as pressure (disconnected system) or centrifugation (continuous system).

Three extraction systems are now in use (Figure 8)

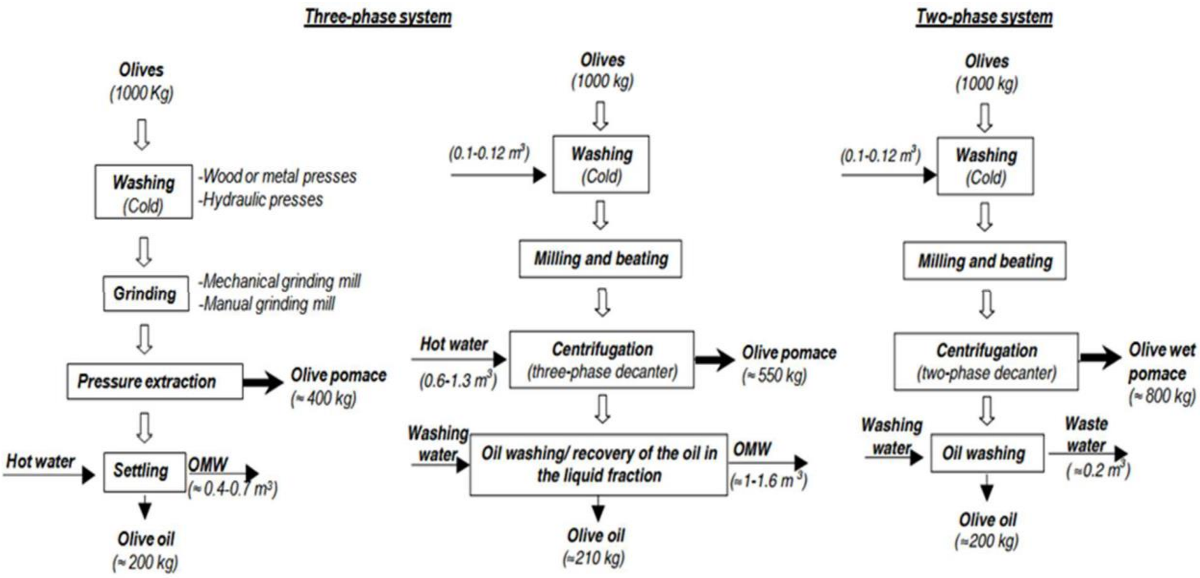

Figure 8 : Comparison between the three different extraction of olive pomace **(ALBURQUERQUE, 2004)**.

Discontinuous (or classic) press system: Press systems are classic systems. They start by crushing the olives, followed by mixing and pressing (**EL HAJJOUJI, 2007**). Three phases are recovered: two liquids, oil and vegetation water (margine), and one solid phase: pomace.

Continuous three-phase process: olives are washed, crushed, mixed with hot water, and kneaded to form the olive paste, which is then diluted **(EL HAJJOUJI, 2007).**

Two-phase continuous system: This technology, first introduced in 1992, separates the paste into two phases (oil and pomace). All the margine is mixed with the pomace. This process is described as environmentally friendly since it eliminates the need to reject margine **(S'HABOU, 2004).**

III.3. Types of olive pomace

Types of olive pomace can be categorized according to their processing and nucleus content. The olive grain refers to the pulp that remains after extracting the olive oil. In part, we will iterate in detail on the main types of olive grind.

III.3.1. Raw pomace

The first type of olive pomace is raw pomace, also known as fresh pomace. This is the solid pulp obtained directly after the olive crushing process. According to a study by **CARUSO ET AL. (2019),** raw pomace generally contains a high level of moisture and non-lipid substances.

III.3.2. Depleted pomace

The second type of olive pomace is exhausted pomace, also known as depleted olive pomace. This type of pomace is obtained after the olive oil has been extracted using mechanical or chemical methods. According to a publication by the **Observatoire des énergies renouvelables (2008)**, spent pomace is composed of olive pulp residues, pits, and a considerable quantity of residual oil. It can be used as fuel or as a raw material in certain industrial processes.

III.3.3. Partially pitted pomace

The last type of olive pomace is partially pitted pomace. As the name suggests, this is olive pulp from which some of the pits have been removed. According to a study by **GAMBARO ET AL. (2017),** this type of pomace can be obtained using specific pitting techniques. Partially pitted pomace retains an interesting residual oil and nutrient content.

In conclusion, the typology of olive pomace can be distinguished according to its processing and stone content. The main types of olive pomace include raw pomace, depleted pomace, and partially pitted pomace. Each type has specific characteristics in terms of composition and potential uses. However, it's important to note that research in this field is constantly evolving, and new variants may be discovered in the future.

III.4. Physicochemical characteristics

Raw pomace contains the pit shell, reduced to pieces, the skin, and the crushed pulp of the olive, about 25% water, and still a certain amount of oil that promotes their rapid deterioration. **(figure 9)**

Exhausted pomace differs mainly in having a lower oil content and a reduced water content due to dehydration during the extraction process.Partially pitted exhausted pomace consists mainly of pulp (mesocarp) and still contains a small proportion of shells that cannot be completely separated by the sieving or ventilation processes used **(FERETTI, SCALABRE, 1978)**

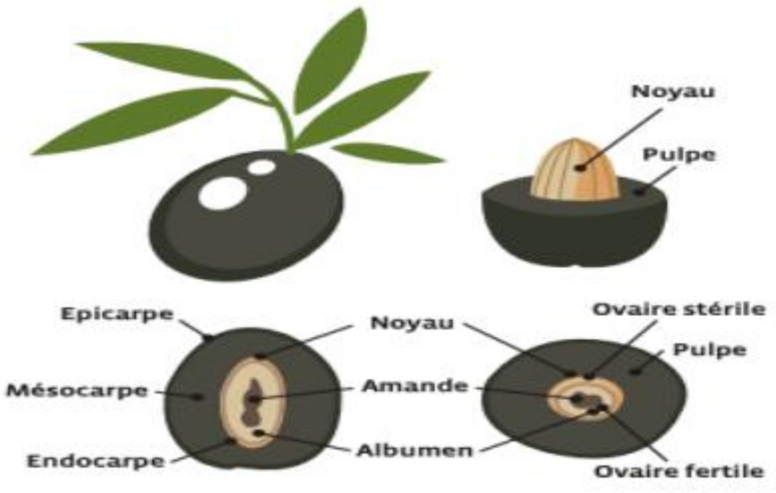

Figure 9 : Transverse and longitudinal sections of olives **(AFIDOL, 2019)**.

Table 2 : Physical Composition of Different Types of Pomace **(NEFZAOUI, 1987)**.

Composition / Product	M.S (%)	Percentage (%) in dry matter			
		Fat	Dry pitt	Dry seed	Mesocarp + epicarp
Olive	51,4	27	14,1	1,3	9
Raw pomace	75,9	9,1	42,1	3	21,2
Exhausted pomace	72,3	4,2	-	5,6	39,3

The chemical composition of olive pomace varies widely depending on the maturity stage, oil extraction processes, and solvent exhaustion. The fat content and crude cellulose exhibit the most significant variations. These variations directly impact the nutritional value of the product **(Nefzaoui, 1987)** Unlike other oilseed cakes, raw pomace is low in nitrogenous matter and high in crude cellulose.

Table 3 : Indicative Chemical Composition of Different Types of Olive Pomace **(D.P.V, 2009)**.

Type	Dry Matter (%)	Mineral Matter (%)	Total Nitrogenous Matter (%)	Crude Cellulose (%)	Fat Content (%)
Raw Pomace	75–80	3–5	5–10	35–50	8–15
Fatty Pomace, Partially Pitted	80–95	6–7	9–12	20–30	15–30
Exhausted Pomace	85–90	7–10	8–10	35–40	4–6
Exhausted Pomace, Partially Pitted	85–90	6–8	9–14	15–35	4–6

The values indicated above are highly variable, especially for raw pomace and fatty, partially pitted pomace, and should only be considered indicative.

It should be noted that these different pomaces come from olives of various origins and have undergone different treatments, which explains the heterogeneity of some results.

III.4.1. Raw Cellulose

As mentioned above, the crude cellulose content is high for unpitted pomace. Partial pitting significantly reduces this content, but even pure pulp contains around 20% crude cellulose.

Fiber analysis by the Van Soest et al. (1975) method reveals that they have very high levels of cell wall constituents (NDF), lignocellulose (ADF), and lignin (ADL) ***(Table 4)*.**

Table 4 : Characteristics of Cell Wall Constituents of Olive Pomace **(NEFZAOUI, 1987)**.

Type	Exhausted Pomace (Tunisia)(1)	Partially Pitted Exhausted Pomace (Tunisia)(1)	Spain (2)	Greece (3)
NDF	72	55	70	83
ADF	60	45	-	64
ADL	31	29	31	24

Sieving paradoxically reduces cellulose more significantly than lignin. This composition of cell wall constituents in olive pomace is comparable to that of cereal straws with an apparently higher degree of lignification.

III.4.2. Total Nitrogenous Matter

Their content varies depending on the type of pomace but remains relatively modest. Protein nitrogen constitutes more than 95% of the total nitrogen and its solubility is particularly low (1.5% of the total nitrogen according to Zelter, 1968, cited by Theriez and Boule, 1970, and Gomez-Cabrera, 1983, personal communication, 3% according to **(NEFZAOUI, 1983).** Moreover, a large part of the proteins (80 to 90%) is bound to the lignocellulosic fraction (ADF-N) **(NEFZAOUI, 1983).**

III.4.3. Lipids

The fat content of pomace is very rich in C16 and C18 unsaturated fatty acids, which constitute 96% of the total fatty acids. Pomace is very vulnerable to atmospheric oxygen, which is largely responsible for the alteration of organoleptic properties. However, Theriez and Boule (1970) noted that the rancid oil of pomace does not seem to be the cause of the drop in digestibility they observed in vitro, with the results obtained from pomace stored for over a year being the same as those from fresh pomace.

The fat content of raw pomace can be a significant energy source, but in the case of exhausted pomace, this contribution is limited.

III.5. Nutritional characteristics

According to **Nefzaoui and Vanbelle (1986)**, the apparent digestibility coefficients (ADC) for raw olive pomace are respectively 26 to 31% for Organic Matter (OM), 6 to 10% for Crude Protein (CP), and 0 to 30% for Crude Fiber (CF). For sieved, exhausted olive pomace, they are 32 to 40%, 29 to 38%, and 21 to 47%. Being highly lignocellulosic, olive pomace has a very slow degradability in the rumen. The maximum values reached (potential degradability) are only 32% after a 72-hour stay in the rumen.

III.5.1.1. Digestibility

The estimation of the apparent digestibility of olive pomace is generally calculated by difference and ignoring any associative effect of other food ingredients. Digestibility varies depending on the type of olive pomace. However, the apparent digestibility of organic matter (OM) and crude protein is low (0.20-0.50), regardless of the type of olive pomace and the processing method **(THERIEZ and BOULE, 1970).**

Molina and Aguilera (1988) found that the apparent digestibility of cell wall components was low (NDF, 0.15; ADF, 0.09; ADL, 0.14), but was improved by adding 5g of NaOH/100g of olive pomace (up to 0.34, 0.28, and 0.28, respectively).

III.5.1.2. Degradability

Olive pomace, being highly lignocellulosic, has a very slow degradability according to **Nefzaoui (1983)**, and the maximum values reached are very modest (32% of the dry matter is degraded after a 72-hour stay in the rumen for sieved, exhausted pomace). The degradability of proteins is also very low, and this can be explained by the fact that 75 to 90% of the nitrogen is bound to the lignocellulosic fraction, resulting in a very low nitrogen solubility of only 2.3% (soluble N % of total N) for raw pomace, and around 0.2 to 0.4% for sieved pomace.

III.5.1.3. Ingestibility

Although ruminants consume olive pomace without adaptation problems, their consumption remains variable. Most of the information available on the ingestion and digestibility of olive pomace relates to dried and raw pomace **(AGUILERA ET MOLINA, 1986; MOLINA ET AGUILERA, 1988)**. It appears that this type of product is ingested in large quantities, especially if it has been previously mixed with molasses. The ingestion of the exhausted sieved results in a dietary behavior very comparable to that obtained with chopped hay. This result is important in itself, because despite the small size of the feed particles in the sieved, it ensures normal rumination (**NEFZAOUI, 1991**). Rations containing alfalfa hay, barley, sunflower flour, and varying proportions (0.2-0.83) of OP, with the addition of beet molasses to encourage ingestion, were consumed satisfactorily (85-130 g DM/day/ $P^{0,75}$ or 1.4-2,2 kg DM/day) by sheep. According to **NEFZAOUI AND VANBELLE (1986**), higher levels of OP were observed in sheep when fed 16 g DM/p0.75/day granules than in enzyme (99 g DM/ $P^{0,75}$ /day). These researchers also found that the granulation of the olive pomace reduced the digestibility of the OM, probably due to a reduction in particle size resulting in a decrease in the retention time in the rumen.

III.5.1.4. Biochemical characteristics of rumen

The few available data are derived from the work carried out in Tunisia **; NEFZAOUI ET VANBELLE 1986** on exhausted sieved pomace.

- Ammoniogenesis is limited when this grignon is distributed ad-libitum to sheep the production of NH3 is in fact below the threshold of 50 mg/l of rumen juice. With rations where 40% barley is replaced with 40% nuts, the NH3 production varies from 64 to 78 mg/l depending on the time of sampling.

- Ingestion of olive pomace alone leads to low production of total volatile fatty acid (51 mM/l). The ratio of different VFA (71% acetic, 19% propionic, and 10% butyric) corresponds to the type of fermentation characteristic of crude feeds (paille, foin).
- The pH of rumen juice from animals fed with olive pomace ranges from 6.6 to 7.2 and is therefore conducive to optimal cellulolithic activity.

III.6. Feed value

The energy value of the pomace is low, it varies between 0.32 and 0.49 NEL and between 0.21 and 0.35 NEp, depending on the proportion of pomace in the diet and the quality of the supplementary ration **(NEFZAOUI, 1985; NEFZAOUI ET VANBELLE 1986).** The digestible nitrogen content is also very low.

III.7. Valorisation of olive pomace

As with straw, alkali treatments have been the subject of most studies.

III.7.1. Soda Treatment

Low amounts of soda, less than 4%, have little effect on the in-vitro digestibility of dry matter. This gradually increases to reach values of 50 to 70% for quantities of 6 to 8% soda **(ABDOULI, 1979; NEFZAOUI, 1979).** Washing and filtering the pomace to remove excess soda reduces digestibility.

Treatment of fatty pomace with soda can lead to soap formation through saponification. This phenomenon was also highlighted **by Karalazoo (1979**). Hence the need to treat only exhausted pomace or to use alkalis (Na2CO3, NH4OH) that do not generate saponification reactions.

III.7.1.1. Influence of Treatment on Chemical Composition

Apart from the predictable increase in ash content, the treatment mainly modifies the contents of cell wall constituents (Table 5) and the nitrogen fraction bound to ADF.

Table 5 : Average contents of cell wall constituents of sieved exhausted pomace, treated or not with 4% soda (6% of DM) **(Nefzaoui, 1979)**

	Untreated	**Treated (6% NaOH/DM)**
NDF	60.1	47.2
ADF	49.9	38.8

Corrected ADL	26.8	17.5
Hemicellulose	10.2	8.3
Cellulose	23.1	21.3
ADF-N/Total N, %	94.9	74.6

III.7.1.2. Influence on Digestive Utilization

The degradability of proteins and dry matter is improved. The in-vivo digestibility of dry matter, and especially that of proteins and crude cellulose, are increased. (Table 6)

Table 6 : Influence of Industrial Soda Treatment on the In-Vivo Digestibility of Sieved Exhausted Pomace.

Ditribution method	**Treatment**	**Coeff. Of apparent digestive use**								
		DM	**OM**	**DNM**	**CC**	**NDF**	**ADF**	**ADL**	**H.C**	**CELL.**
Distributed alone, thibar's black rams	Untreated	48	50	32	47					
	Treated 4%NaOH	52	52	43	55					
Molasses in pellets distributed with 100 g hay and 1.5% urea, texel sheep	Untreated	31	32	39	23	24	18	14	49	26
	Treated 4%NaOH	35	36	46	33	33	26	23	62	29
Concentrate of 40% pomace, 49% barley, 8% molasses and 3% minerals, black rams from thibar	Untreated	68	70	59	49					
	Treated 4%NaOH	74	75	65	61					
	Treated 4%NaOH+ 1.5% urea	71	74	70	58					

The already significant intake is not increased. However, the animal's water consumption is more than doubled and urinary excretion more than tripled.

III.7.2. Ensiling with Alkalis

Micro-silo studies (1,51) have demonstrated a significant improvement in "in situ" digestibility with high doses of sodium hydroxide (8%), which is superior to that obtained with ammonia (Table 7).

Table 7 : In Situ Digestibilities of Silages of Sieved Exhausted Pomace Treated with Alkalis **(NEFZAOUI, et al., 1982)**.

	DM	**OM**	**ADF**	**TNM**
Control	51.68	51.23	36.73	59.32
Ammonia 2%	60.25	61.53	45.88	81.34
"4%	58.32	60.36	38.89	83.80
"6%	63.04	63.86	48.18	86.90
"8%	64.28	65.34	49.87	89.54
Soda 4%	62.86	62.00	46.63	72.84
"6%	62.46	60.55	47.17	73.93
"8%	78.51	77.67	62.04	79.35

III.7.3. Ammonia Treatment

Pre-molassed sieved exhausted pomace was stored in plastic bags with NH_3 injection (3%). This resulted in a significant improvement in nutritional value (Table 8), notably by:

- An increase in nitrogen content (+ 200%).
- An improvement in the digestibility of all nutrients, particularly nitrogenous matter (+ 90%).
- An increase in nitrogen retention.

Table 8 : Digestibility, Ingestion, and Nitrogen Balance of Sieved Exhausted Pomace Ensiled with Ammonia **(NEFZAOUI, et al., 1983).**

	Not treated	**Treated 3% of NH_3**
Digestibility%		
DM	36	41
OM	40	43
TNM	29	55
FM	77	86
CC	39	49
NDF	32	39
ADF	25	32
ADL	13	19
Hemi-cellulose,	60	63
Cellulose	43	49
Ingestion g DM/d/$P^{0.75}$	99	98
Nitrogen balance: g N/d/$P^{0.75}$	1,903 (100%)	3,610 (100%)
Ingested	1,353 (71%)	1,632 (45%)
Fecal	0,240 (13%)	1,147 (32%)
Urinary	0,310 (16%)	0,831 (23%)
Retained		

III.7.4. Ensiling Sieved Pomace with Poultry Litter

Studies conducted by Nefzaoui and Deswysen (1982) have shown that silages containing 70% poultry litter that has been accumulated for less than 21 days and 30% sieved exhausted pomace are excellently preserved (according to FLIEG evaluation criteria).

III.7.5. Treatment with Na2CO3

Vaccarino et al (1982) compared treatments with different doses of NaOH and Na2CO3 on partially pitted pomace for 150 minutes at 70°C before addition solvent. Both methods significantly improve in-vitro digestibility, soda is however more effective (Table 9)

Table 9 : Effects of Treatments of Partially Depitted Pomace with NaOH or Na2CO3 on In-Vitro Digestibility **(VACCARINO et al., 1982)**

	Control	**Na OH%**			**Na2 CO3, %**		
		2,9	5,7	8,6	3,8	7,2	11,4
Degestibility of organic matter	15,8	20,7	32,3	50,8	26,9	40,6	47,9
Degestibility of dry matter	9,7	8,8	27,2	31,9	5,1	39,4	46,5

III.7.6. Mechanical Treatment

The only practical mechanical treatment consists of the partial separation of the husk from the pit by sieving or ventilation. This significantly reduces the crude cellulose content (see Table 3) and true cellulose but paradoxically very little the lignin content (see Table 4).

Referring to Table 6, the effect of partial depitting on the digestibility of non-exhausted pomace is not evident: the results are so few and heterogeneous that no precise conclusions can be drawn.

However, recent work **(Nefzaoui et al., 1983)** comparing non-sieved exhausted pomace treated with different alkalis (Figure 5) showed that sieving alone improved:

- The digestibility of organic matter by 10 to 15 points, slightly less than soda or ammonia treatments but better than Na_2CO_3 and urea.
- The digestibility of nitrogenous matter by about 30 points, significantly better than all other treatments.

Sieving, therefore, appears to be a very effective method for improving the nutritional value of exhausted pomace.

III.8. Olive pomace preservation

The main problem in preserving raw olive pomace is its relatively high water content and the presence of a still significant amount of fat. When left in the open air, this pomace quickly becomes rancid and soon becomes inedible for animals.

It is estimated that raw pomace obtained by centrifugation, which is more humid, deteriorates after 4-5 days, while pomace obtained by pressing lasts about 15 days. These same dehydrated pomaces would hardly keep for more than 45 days. On the other hand, exhausted pomace that has also been dehydrated during extraction could be preserved for more than a year **(SANSOUCY, 1984)**.

Dehydration is currently an expensive process given the high cost of the necessary energy. Moreover, in the case of raw pomace still rich in fat, its effectiveness as a preservation method seems very limited **(ELHACHEMI, 2010).**

The few small-scale trials of preservation by silage suggest a simpler, more economical, and more effective preservation possibility using the molehill-silo method, which allows for storing very variable quantities from a few tons to several hundred tons **(NEFZAOUI, BEN SALEM, 1996)**

Given that fresh raw pomace keeps for a very short time, it must be distributed very quickly to animals or ensiled as soon as possible to avoid spoilage **(FERETTI, SCALABRE, 1978).**

It should be noted, however, that it is generally more economically profitable to extract the oil from the pomace beforehand, but when for specific reasons extraction does not take place, this raw pomace can be preserved for later distribution to animals **(AFIDOL, 2019).**

III.9. Environmental impact of olive pomace

Olive oil mill effluents (olive pomace) are poorly biodegradable due to the phytotoxic and antimicrobial substances (phenols, fatty acids, etc.) they contain. Simple treatments are not sufficient to ensure their processing, which necessitates appropriate management to prevent their negative impact on the environment (**SIFOUN, 2008)**

III.9.1.1. Impact on water

Often discharged into natural receptors without any prior treatment, olive oil mill effluents severely harm the quality of surface waters. The very high DCO and DBO load prevents waters from self-purifying, and pollution can extend over very long distances. The polyphenols contained in olive oil mill effluents, discharged into low-flow watercourses where air exchange is limited, exert an antagonistic action on aquatic flora and fauna, often causing their death **(EL HAJOUIJI et al, 2007).**

III.9.1.2. Impact on soils

Olive pomace also presents some drawbacks, including the difficulty of incorporating it uniformly into the soil, and its toxicity to plants due to its significant quantity of polyphenols (**AMRANE et al, 2017).**

III.9.1.3. Impact on plants

Phenolic compounds are the major contributors to the phytotoxicity of olive oil mill effluents. The direct application of these raw effluents reduces the dry matter yields of soybeans and tomatoes Consequently, the direct spreading of olive oil mill waste has negative repercussions on water, soil, microorganisms, and plants. Hence the need to treat these effluents in order to mitigate the environmental problems they cause **(EL HAJOUIJI et al, 2007).**

IV. Introducing olive pomace into dairy cow feed

IV. Introducing olive pomace into dairy cow feed

Olive pomace, the solid residue from olive oil extraction, can be used as a supplement in animal feed, offering several benefits:

Nutritional Value: Olive pomace is rich in fiber, fats, and antioxidants, which can enhance the nutritional value of animal diets **(CHIOFALO, et al.,2004)**

Improved Digestion: The high fiber content of olive pomace promotes better digestion and optimal nutrient absorption **(MOLINA, 2008)**

Cost Reduction: Utilizing olive pomace, which is often available at a lower cost, can reduce expenses associated with animal feed **(IOC, 2016)**

Antioxidant Properties: The phenolic compounds present in olive pomace possess antioxidant properties, helping to protect animal health by reducing oxidative stress **(FAO, 2017)**

IV.1. Effects of olive pomace on the chemical composition of milk & its quality

Olive oil pomace (OOP), a by-product of olive oil milling, shows promise for enhancing milk's nutritional value. Rich in soluble polyphenols (PPs) such as hydroxytyrosol and tyrosol, OOP contains compounds widely recognized in the scientific literature for their antioxidant and anti-inflammatory properties. **(ARAUJO et al., 2015; MEDEIROS-DE-MORAES et al., 2018; NEOFYTOU et al., 2020; TZAMALOUKAS et al., 2021)**

Olive oil pomace from the two-phase milling process contains higher levels of polyphenols (PPs) and water (75%) compared to that from the three-phase process. While drying is the most common preservation method, this thermal treatment oxidizes PPs and polyunsaturated fatty acids (PUFAs), diminishing the nutritional value of the olive oil pomace. **(NEOFYTOU et al., 2021)**. Updated modern milling systems have addressed the issue of stone content, resulting in olive oil pomace (OOP) that is more digestible for animals. **(MANNELLI et al., 2018)**. Incorporating fresh, destoned olive oil pomace (OOP) from the two-phase process into ruminant diets is preferable. This approach increases polyphenol content, which can modulate microbial activity and protect polyunsaturated fatty acids

(PUFAs) from lipolysis and biohydrogenation. **(CAPPUCCI et al., 2018; MANNELLI et al., 2018)**

IV.1.1. <u>Study 01:</u> **(MANNELLI et al., 2018)**

Forty multiparous Italian-Friesian dairy cows, at middle lactation, were randomly allotted into two homogenous groups and fed respectively a commercial diet (CON) and the experimental diet (OOPD) obtained by adding OOP to CON as a partial replacement of maize silage. The two diets were formulated to be isoproteic and isoenergetic. The same diets were also tested in an in vitro trial aimed at evaluating their rumen degradability (% DEG) **(MANNELLI et al., 2018).**

- Outcome
  - Animal performances

No animal was excluded during the whole period of the trial. Animals were fed completely the daily rations, and no daily orts were found, showing a comparable palatability between CON and OOPD. Indeed, no differences were observed for daily DM intake. Milk production did not differ between CON and OOPD groups. Moreover, the pH of RL was not different among the two groups and was in an optimal range **(MANNELLI et al., 2018).**

  - Diet degradability

No differences among groups were found for the % DEG of CP and of NDF **(MANNELLI et al., 2018).**

- Rumen fatty acid and methane potential

Acetate content did not show significant differences between RLs from animals fed the two diets (CON vs OOPD)**(MANNELLI et al., 2018).**

Since the CH4 emission is strongly linked to the stochiometric ratio among volatile FAs, using the equation of **Moss et al. (2000)**, MPP has been calculated for each diet. The estimated CH4 production was higher in CON than in OOPD**(MANNELLI et al., 2018).**

- Milk fatty acid profile and polyphenols content

The milk FA profile reflected the effect of OOPD on rumen FA metabolism. It resulted that the milk from cows fed OOPD showed a FA profile characterized by a lower content in medium-chain FAs and a higher content in PUFAs, MUFAs, and long-chain FAs (carbon chain > 16). The decrease of medium-chain FAs is desirable due to an increase in the nutritional value of milk, since these FAs are detrimental to human health **(HADROVA et al., 2019).** All these FAs are considered protective against cardiovascular disease and carcinogenesis and so positive for human health **(MINIERI et al., 2020).**

IV.1.2. Study 02: **(BOUKHALEF,2009)**

Eighteen lactating goats of the local northern Moroccan breed were divided into two homogeneous batches of nine individuals called T (control "*témoin*") and Ts (olive pomace) respectively. The two batches were fed an identical basic ration of oat hay. Batch (T) received a concentrate consisting of barley, wheat bran, corn, molasses and faba bean. Barley was partially replaced by dried olive pomace (Ts, 29%). The two rations distributed are iso-energetic and iso-proteinic **(BOUKHALEF,2009).**

- Outcome:

The incorporation of olive pomace into the ration of dairy goats had no effect on either milk production nor on the physicochemical composition of the milk. Medium-chain fatty acids were low in batch Ts milk. In contrast, long-chain fatty acids and mono-unsaturated fatty acids were high in the milk from this batch.

The absence of any negative effect of incorporating olive pomace into the ration of lactating goats on production levels and physicochemical composition is in line with the results reported by **Pauselli et al. (2008)** for *Comisana* ewes fed a ration containing 400 g/d DM of dried olive pomace. The high proportion of long-chain and MUFAs in the milk of batch (Ts) is mainly due to the polyphenols contained in olive pomace, which can reduce the microbial activity involved in the bio-hydrogenation of oleic acid to stearic acid in the rumen. The reduction of saturated fatty acids and the increase of unsaturated fatty acids can improve the nutritional quality of milk.

IV.1.3. Study 03: **(CASTELLANI, 2017)**

Twenty lactating Holstein Friesian cows were randomly allocated to two groups of ten animals each, homogeneous for milk yield, parity and DIM. Each group was randomly assigned to a basal diet (CON) and a CON integrated with dried olive pomace (DOP). **(CASTELLANI , 2017).**

- Outcome

Lipolysis is one of the biochemical processes responsible for the production of the volatile compounds in milk and dairy products. Dietary integration with dried olive pomace seems to influence the evolution of some lipolytic catabolites in raw milk and pasteurized milk and cheese. DOP integration modified free fatty acids (FFA) and it was particularly evident in raw milk for hexanoic, octanoic, decanoic and dodecanoic acids. **(CASTELLANI et al., 2017).**

Data reported in the study of A. Buccioni, 2023, confirm that the use of OOP in dairy cow feeding can be an interesting strategy to improve milk nutritional quality increasing functional FA content without compromising the rumen degradability of the diet or causing strong perturbation of rumen ecosystem and maintaining animal performances.

Based on the study of Castellani F, 2017, The use of olive pomace in the diet of dairy cows modifies the development of individual lipolytic volatile compounds in raw milk and pasteurized milk cheese.

IV.2. Olive Pomace Oil Impact on Blood Lipids & CVD's risk factors

IV.2.1. Study (4): (GONZÁLEZ-RÁMILA et al., 2022)

This study aimed to assess the effect of dietary consumption of olive pomace oil (OPO) on blood lipids (primary outcome) and other cardiovascular disease (CVD) risk factors (blood pressure, inflammation and endothelial function as secondary outcomes) **(GONZÁLEZ-RÁMILA et al., 2022).**

A controlled intervention was carried out in healthy and at-risk (hypercholesterolemic) subjects. Participants consumed daily diets based on OPO or HOSO as control oil **(S. GONZÁLEZ-RÁMILA et al., 2022).**

- Outcome:

OPO significantly reduced low-density lipoprotein cholesterol (LDL-C) and apolipoprotein B (Apo B) serum concentrations, and the LDL/HDL ratio in healthy and at-risk volunteers. These effects were not observed with HOSO. Blood pressure, peripheral artery tonometry (PAT), endothelial function and inflammation biomarkers were not affected **(GONZÁLEZ-RÁMILA et al., 2022).**

Based on Vasilopoulou D., et al. 2020, studies they concluded that by reducing low-density lipoprotein cholesterol and all that above, olive pomace oil (OPO) helps prevent cardiovascular disease (CVD). These hypolipidemic effects contribute to improved lipid profiles, which are key factors in reducing the risk of CVD.

Regular consumption of OPO in the diet could have hypolipidemic actions in subjects at cardiovascular risk as well as in healthy consumers, contributing to CVD prevention **(GONZÁLEZ-RÁMILA et al., 2022).**

IV.3. Economic impacts of the use of olive cakes in animal nutrition

Despite its chemical, physical and nutritional properties, which are also observed in low quality forages, some research indicates that olive cakes can substitute at relatively high rates some imported ingredients in the diet of rabbits and ruminants. Based on the results of previous research, this simulation analysis shows that the introduction of olive cakes in the diet of animals in Tunisia is very beneficial for both the farmer and the government. The substitution of the concentrate or of one of its constituents by olive cakes, within an optimal rate of substitution, could offer farmers an important income gain. The introduction of olive cakes in food blocks for sheep during the scarcity period, as a partial substitute concentrated, could lead to higher incomes for farmers.

IV.3.1. Study (05): (REJEB GHARBI et al., 2007)

Feed accounts for 60-80% of total production costs for cattle **(REJEB GHARBI et *al*, 2007)**, sheep and rabbits **(BEN RAYANA et *al*, 1994)**. The limitation of forage resources, resulting in low forage potential, a lack of mastery of production technology and highly unpredictable climatic conditions, is primarily responsible for the heavy dependence on imported feedstuffs for concentrate production, notably soybean meal, barley and maize **(GHARBI et *al*, 2011)**.

Higher production costs for animal products (milk and meat), and the low competitiveness of livestock farming at the farm level have a negative impact on the country's agricultural trade balance **(GHARBI et *al*, 2011).**

- Outcome:

The incorporation of olive pomace into animal feed in Tunisia certainly has varying degrees of impact on farmers' incomes and on the state budget. These effects vary according to the nature of the pomace, the rate at which it is added to the ration, and the performance achieved by each type of livestock.

- **The economic impact of using pomace as a feed maintenance or rescue food impact on farmers' income**

Research results in Tunisia and around the world have shown that the introduction of 30-45% crude pomace in multi-nutritional feed blocks enhances the value of diets rich in roughage, such as rangeland and backup diets based on straw and poor-quality hay. For a daily sheep diet consisting of dry roughage and a certain amount of concentrate per head per day, the introduction of a lesser amount per head per day of feed blocks containing 40% crude pomace enables the substitution of 50 to 70% of the amount of concentrate consumed, while maintaining the same animal performance **(BEN SALEM et al., 2001).**

- **Impact on the value of the change in the trade balance**

The quantity of concentrate likely to be replaced by pomace-based blocks is estimated at a certain weight. This quantity, which would be reduced by our imports of feed used to produce the concentrate, is estimated at a certain amount of money **(GHARBI et al., 2011)**.

Overall, the use of raw pomace is estimated at a lesser weight. The domestic use of raw pomace leads to the cancellation of its export which leads to a loss in foreign currency **(GHARBI et al., 2011)**.

The overall trade balance (import-export) shows a gain in foreign currency estimated at a lesser amount of money **(GHARBI et al., 2011)**.

According to Gharbi et al., 2011:

- Substituting concentrate with olive cake in animal feed can positively impact the agricultural trade balance in Tunisia.
- The economic analysis shows that the substitution is beneficial as long as the local price of olive cake is lower than that of the concentrate.
- Different scenarios for substituting feed ingredients with olive cake demonstrate potential cost savings and improved profitability for livestock farmers.

Conclusion

Olive by-products, particularly olive pomace, represent a significant yet underutilized feed resource for ruminants in Mediterranean regions. Recent studies have explored the potential of these by-products, focusing on their impact on animal performance and product quality.

Research findings indicate that incorporating olive pomace into ruminant diets, especially for dairy cows, can enhance milk quality. Specifically, it increases the content of monounsaturated fatty acids while reducing saturated fatty acids in milk. Although olive pomace doesn't necessarily increase milk production, some studies have shown yields comparable to those achieved with conventional feed rations.

The most promising method for utilizing olive pomace appears to be its incorporation into multi-nutrient blocks. This approach effectively meets the nutritional needs of ruminants, particularly dairy cows, while simultaneously helping to reduce feed costs.

Beyond nutritional benefits, the use of olive pomace in livestock feed offers significant environmental advantages. It contributes to waste reduction by lowering costs associated with disposal and decreasing organic waste load.

However, the full potential of olive pomace in animal nutrition is yet to be fully realized. Further research is necessary to optimize its use and to explore its effects on the overall quality of various animal products. As investigations continue, olive pomace could play an increasingly important role in developing sustainable and cost-effective livestock feeding strategies in Mediterranean regions.

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