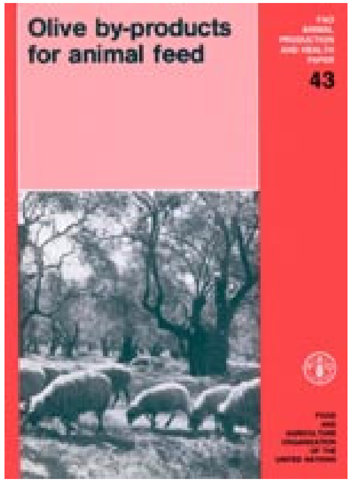

FAO ANIMAL PRODUCTION AND HEALTH PAPER 43

Olive by-products for animal feed

CONTENTS

Review by
René Sansoucy (FAO, Rome)
based on studies made by:
X. Alibes and Ph. Berge, in Spain
F. Martilotti, in Italy
A. Nefzaoui, in Tunisia
P. Zoïopoulos, in Greece

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CONTENTS

FOREWORD

This document is a review of present information on possibilities of using harvest residues and olive oil industry by-products in animal feeding. This review is based mainly on the reports made by four experts in animal feeding for the Food and Agriculture Organization of the United Nations. Those reports are available in limited quantity from the Animal Production and Health Division of the Organization for specialists who wish to have more detailed information on the work done in one of the four countries which were the subject of those studies. They were published in the language of the original document and have not been translated:

- Valorización de los subproductos del olivar como alimentos para los rumiantes en España — by X. Alibes and Ph. Berge Animal Production and Health Division, FAO, Rome, 1983

- Use of olive by-products in animal feeding in Italy
  by Fernanda Martilotti
  Animal Production and Health Division,
  FAO, Rome, 1983

- Etude de l'utilisation des sous-produits en alimentation animale en Tunisie
  by A. Nefzaoui
  Animal Production and Health Division,
  FAO, Rome, 1983

- Study on the use of olive by-products in animal feeding in Greece
  by P.E. Zoiopoulos
  Animal Production and Health Division,
  FAO, Rome, 1983

When considered useful, some information from other countries which does not appear in these reports has been added to complete this review.

After describing all the research conducted and the information acquired until now, practical recommendations and research subjects to be pursued have been suggested.

The authors wish to stress the benefits they received from the collaboration offered them by the Regional Project RAB/79/027 on Olive Production Development, the FAO/UNDP, the International Olive Oil Council, and the different institutions and specialists who helped to supply the information which made this study possible.

It is hoped that this document will be useful to researchers on animal feeding, agricultural advisers responsible for transmitting new techniques, the farmers and stock-raisers who should be the beneficiaries of these studies and to managers of the olive industry who wish to valorize their by-products to greatest advantage.

René Sansoucy
Specialist in Animal Production (Feed Resources)
Animal Production and Health Divison
FAO - Rome

CHAPTER I: IMPORTANCE OF OLIVE PRODUCTION AND OLIVE TREE BY-PRODUCTS

1.1 Olive production

Although olive tree production is distributed over all five continents (see Table 1), it prevails especially in the Mediterranean Basin which represents 98 percent of the production area and trees and 97 percent of all olive production.

The four countries (Spain, Greece, Italy and Tunisia) examined in this study represent by themselves:

- **65 percent of the area**
- **76 percent of the trees in production**
- **74 percent of total olive production**

On a world scale the importance of olive production can be summed up by the following four figures (rounded out):

Table 2: Size of world olive production

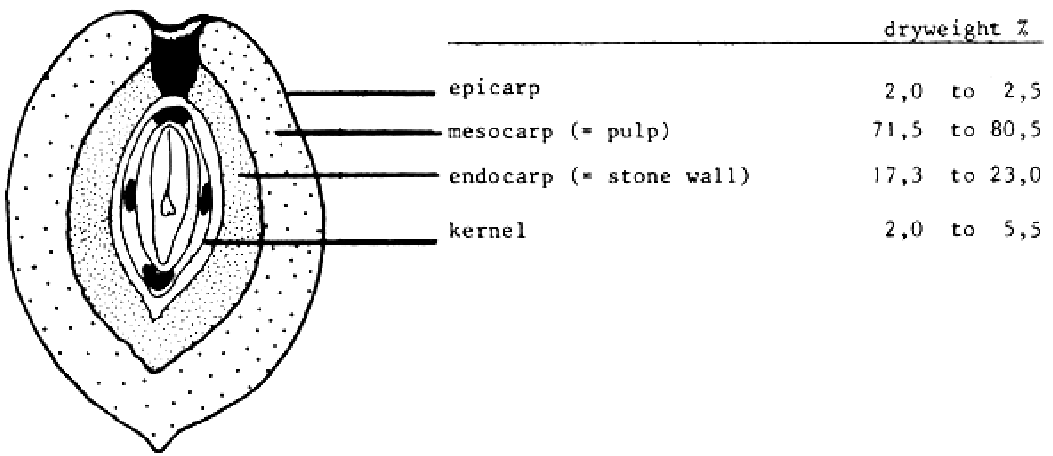
- total area	:	7 000 000 ha
- trees in production	:	600 000 000
- olives produced	:	8 400 000 tons
- oil produced	:	1 600 000 tons

Olive cultivation has a social character, since it employs abundant labour and involves many small producers. On the other hand, production is seasonal which has repercussions on job conditions and the availability of by-products.

1.2 Olive composition

The olive is a drupe; its physical composition is shown in Fig. 1

Figure 1: The olive: (a) cross-section and (b) physical composition



a) from Maymone et al, 1961

b) Nefzaoui, 1983

Table 1: Importance of olive production in the main producer countries

Country	Plantations (1)			Production (2)	
	Area (1 000 ha)	Plants in production (x 1 000)	Density (plants/ha)	Olives (1 000 T)	Oil (1 000 T)
Europe					
Albania	20	1 500	75	53	7
France	30	3 800	130	16	2
Greece	420	79 000	190	1 350	280
Italy	1 200	160 000	133	2 800	566
Portugal	480	26 000	54	220	33
Spain	2 300	180 000	78	1 348	281
Yugoslavia	60	4 700	78	13	2
Africa					
Algeria	125	10 000	80	100	11
Egypt	2	100	50	6	0.5
Libya	154	4 000	26	162	16
Morocco	140	6 700	48	350	38
Tunisia	600	37 000	62	700	140
Asia					
Turkey	1 200	59 000	49	650	107
Other	137	14 000	102	395	68
America	122	12 800	105	214	29.7

Australia	-	40	-	6	0.6
TOTAL	6 990	598 740	86	8 383	1 581.8

Sources:

(1) From Fertimont, “Mondo Economico” No. 3, 23 January 1983

(2) From FAO: Statistics Series No. 40, 1982

1.3 Oil manufacture

The technology used is very varied and has been modified considerably during recent decades. As an example, two methods are described below:

- **extraction by pressure: Tunisia (Fig. 2)**
- **extraction by centrifugation: Italy (Fig. 3)**

and the percentages of oil and by-products obtained (olive cakes and vegetation waters) are given.

There are also other procedures such as the Acapulco method which consists of previously separating the stone from the pulp.

1.4 Main by-products

1.4.1 Definitions

It is important to define the different by-products since there is some confusion in the publications which makes it sometimes difficult to identify clearly the particular by-products concerned. The following definitions are therefore given:

a. <u>Oil extraction by-products</u>

- <u>crude olive cake</u>: The residue of the first extraction of oil from the whole olive by pressure. Its relatively high water (24%) and oil (9%) content cause rapid spoilage when it is exposed to air.
- <u>exhausted olive cake</u>: The residue obtained after extraction of the oil from the crude olive cake by a solvent, usually hexane.
- <u>partly destoned olive cake</u>: The result of partly separating the stone from the pulp by screening or ventilation:
- it is called “fatty” if the oil has not been solvent-extracted.
- it is called “exhausted” or “defatted” if the oil has been solvent-extracted.
- <u>olive pulp</u>: The paste obtained when the stone has been separated from the pulp before extraction of the oil. It has a high water content (60%) and is difficult to store.
- <u>vegetation waters</u>: The brown watery liquid residue which has been separated from the oil by centrifugation or sedimentation after pressing (Fedeli and Camurati, 1981).
- <u>leaves collected at the oil mill</u>: These are not pruning residues, but the leaves obtained after the olives have been washed and cleaned on entering the oil mill. In Greece their estimated quantity is about 5 percent of the weight of the olives (Zoiopoulos, 1983).

b. <u>Pruning and harvest residues</u>

Olive trees are usually subjected to severe pruning every second year and light pruning in the alternate year. After separation of the large branches, the leaves and twigs (less than 3 cm in diameter) can be distributed to ruminants.

1.4.2 Estimated quantities of olive by-products

The quantities can vary according to the manufacturing process. Average estimated values are summarized in Figure 4. Taking 35 percent as the average value for proportion of crude olive cake to processed olives, world crude olive cake production can be estimated at about 2 900 000 tons.

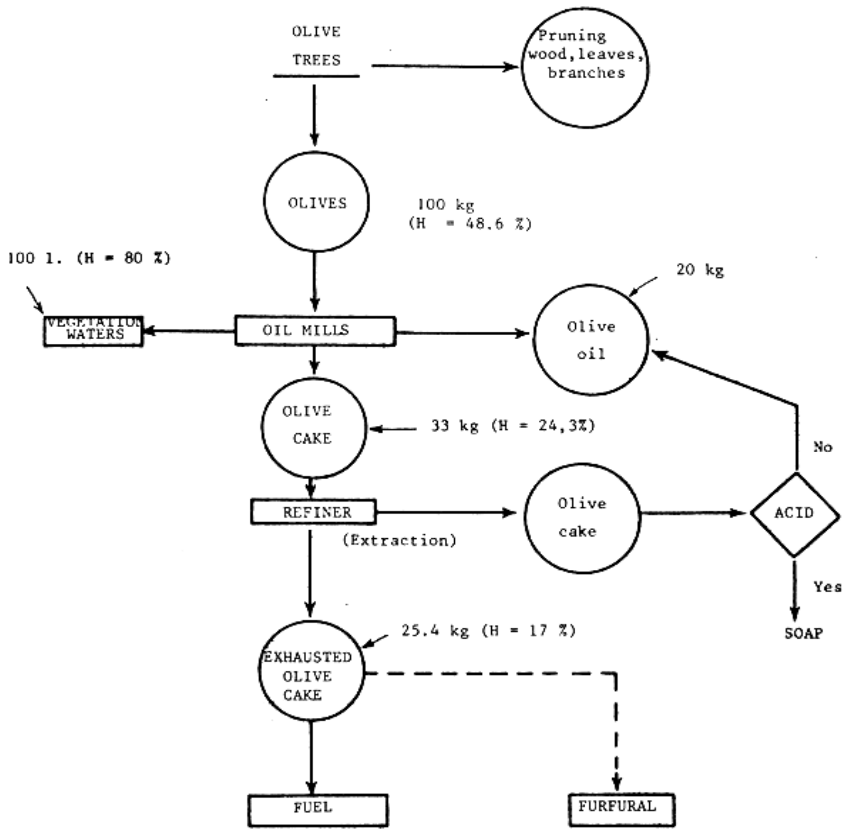


Figure 2. **Diagram of the present olive oil industry in Tunisia**

Source: **Nefzaoui, 1983**

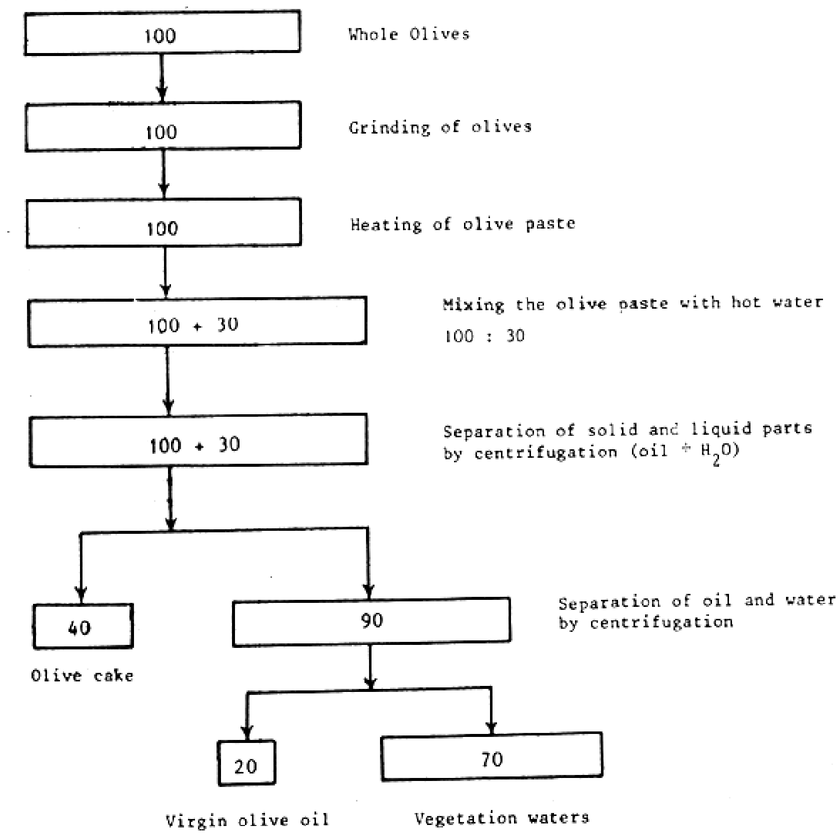


Figure 3. **Pieralisi oil extraction mill in lazio (Italy): olive processing by centrifugal separation**

Source: **Martilotti, 1983**

Figure 4: **Method of obtaining different types of olive cake and physical composition (Feretti method)**

Method	Ratio	By-products	Physical Composition %
	100 kg	OLIVE	water : 48.6
			oil : 27
Pressing			dried stones : 14.1
			kernels : 1.3
			mesocarp+
			epicarp : 9
	33 kg(1)	CRUDE OLIVE CAKE	water : 24,3
	(33%)		oil : 9.1
Solvent extraction			dried stones : 42.4
			kernels : 3
	16.7 kg(2)	SCREENED OLIVE CAKE	water : 37.7
	(50.5%)		oil : 16.8
Screening-Ventilation			dried stones : 5.6
			dried kernels : 5.6
			mesocarp +
			epicarp : 39.9
	7.41(3)	EXHAUSTED SCREENED	water : 4.5
	(44%)	OLIVE CAKE	
			oil : 4.2
			dried stones : -
			dried kernels : 11.1
			mesocarp +
			epicarp : 80.2

Source: Adapted from Feretti and Scalabre, 1978
(1) Part of the mesocarp and the epicarp are lost in vegetation waters.
(2) Screening losses as dust, about 5 percent.
(3) On emerging from extraction olive cake contains about 17 percent water and is dehydra-ted again.

N.B. When crude olive cake is defatted without being destoned, the exhausted olive cake then represents about 77 percent of crude olive cake and has the following composition: water, 15%; oil, 4%; shells, 55%, pulp, 26%.

Source: Office National de l'Huile (National Oil Bureau), Tunisia.

The percentage of crude olive cake treated by solvents to extract the oil from the cake varies widely according to the country, reaching 80 percent in Greece and Tunisia. There is a marked tendency to increase the quantity of olive cake subjected to oil extraction by solvents.

Exhausted olive cake partly destoned by screening or ventilation is not widespread at present. After destoning, it represents about 44 percent of the original exhausted olive cake. Several studies have been undertaken for its valorization, especially in Tunisia, but have not been developed on an industrial scale.

The vegetation waters eliminated constitute a large quantity of polluting effluents and most countries are now concerned by this pollution problem. In pressure extraction methods about 100 litres of vegetation water are obtained per 100 kg of olives processed.

Concerning olive tree leaves and twigs, Nefzaoui (1983) made the following estimates of quantities produced (Table 3):

Table 3: Quantities of wood, leaves and twigs obtained according to age of olive tree and type of pruning

Age of tree	Pruning type	Total quantity of wood kg/tree	Leaves and twigs %	Quantity of leaves and twigs kg/tree
young	light	-	-	-
	severe	30	60	18
adult	light	50	50	25
	severe	100	30	30
old	light	-	-	-
	severe	100	12	12

Recent research by Vera y Vega and Galan Redondo (1978), Civantos (1981 b and 1982) and Parellada et al (1982) have attemped to estimate olive tree branch and leaf production in different conditions in Spain. Yields vary widely from 10 to 25 kg and can reach as much as 45 kg for olive trees in favourable cultivation conditions. Weighted average per tree is probably about 22 kg of twigs according to Parellada and Gomez-Cabrera (1983). These estimates agree on the whole with those of Nefzaoui (see Table 3).

CHAPTER II: OLIVE CAKE

2.1 Physical characteristics

Crude olive cake contains the olive kernel shell crushed into fragments, the skin and the crushed pulp, about 25 percent water and a remaining quantity of oil making them subject to rapid spoilage.

Exhausted olive cake differs from crude olive cake mainly by lower oil content and a smaller water content because it has been dehydrated during the extraction process.

Partly destoned exhausted olive cake consists mainly of pulp (mesocarp) and still contains a small proportion of shell which cannot be completely separated by the screening or ventilation methods employed.

Figure 4 gives the yields of different types of olive cake from treated olives and their respective physical composition.

2.2 Conditions of olive cake preservation

The main problem in preserving crude olive cake is its relatively high water content and the still large quantity of oil it retains. When exposed to air this type of olive cake quickly becomes rancid and unfit for animal consumption.

It has been estimated that crude olive cake obtained by centrifugation, being wetter, deteriorates after 4–5 days, whereas olive cake obtained by pressure deteriorates after about 15 days; dehydrated, the same olive cake probably could not be stored longer than 45 days. On the other hand, exhausted olive cake which has also been dehydrated during the extraction process could be stored for over a year.

At present dehydration is a costly process in view of the high cost of the energy required. Furthermore, in the case of crude olive cake which still has a high oil content, its effectiveness as a preservation method appears to be very scarce. The few small-scale silage storage tests made suggest a possibility of simpler, more economic and more efficient preservation using the stack-silo method which allows storage of quantities varying widely from a few to several hundred tons.

Considering the fact that crude olive cake only keeps for a very short time, it should be distributed quickly to animals or ensiled as soon as possible so that it does not spoil.

However, it should be mentioned that it is usually more economically profitable to extract the oil from the olive cake beforehand, but that when for certain reasons the oil has not been extracted the crude olive cake can be stored for distribution to animals later on.

2.3 Chemical characteristics

2.3.1 Chemical composition of olives

For easier understanding of the variations in the chemical composition of different types of olive cake it may be useful to review (Table 4) the chemical composition of the various components in olives.

Table 4: Chemical composition of ripe olive components

Part	Crude Protein	Ether extract	Crude Fibre	Ash	Nitrogen-free extract
Epicarp	9,8	3,4	2,4	1,6	82,8
Mesocarp	9,6	51,8	12,0	2,3	24,2
Endocarp	1,2	0,8	74,1	1,2	22,7

(stone and					
kernel)					

Source: Maymone et al, 1961

Obviously the part with the highest oil content is the mesocarp (or pulp) and that which the highest crude fibre content is the endocarp (or stone).

2.3.2 Chemical composition of olive cake

Unlike other oil cakes, crude olive cake has a low crude protein and high crude fibre content. It retains a relatively high fat content. Exhaustion by solvent extraction decreases its fat content and relatively increases its other contents. Partial destoning by screening or ventilation lowers its crude fibre content. (Table 5).

Because the kernel is totally separated before pressure extraction, the pulp has the lowest crude fibre content.

Table 5: Indicative chemical composition of different olive cake types

		% of dry matter			
Type	**Dry matter**	**Ash**	**Crude Protein**	**Crude Fibre**	**Ether Extract**
Crude olive cake	75–80	3–5	5–10	35–50	8–15
Partly destoned olive cake	80–95	6–7	9–12	20–30	15–30
Exhausted olive cake	85–90	7–10	8–10	35–40	4–6
Partly destoned exhausted					
olive cake	85–90	6–8	9–14	15–35	4–6

Fatty pulp	35–40	5–8	9–13	16–25	26–33

Sources: many authors.

The values given above vary widely, mainly for crude olive cake and partly destoned fatty olive cake, and can only be considered indicative.

It should be mentioned that these different cakes are obtained from olives of various origins and have been subjected to different treatments which accounts for the heterogeneity of some results.

a. **Crude fibre**

As mentioned above, the crude fibre content in destoned olive cake is high. Partial destoning decreases the content considerably but even pure pulp contains about 20 percent crude fibre.

Analysis of fibres by the Van Soest (1975) method shows that olive cake has high cell wall constituents (NDF) and ligno-cellulose (ADF) and lignin (ADL) contents (Table 6).

Table 6: Characteristics of olive cake cell wall constituents

	Exhausted olive cake	Partly destoned exhausted olive cake		
	(Tunisia)(1)	Tunisia (1)	Spain (2)	Greece (3)
N.D.F.	72	55	70	83
A.D.F.	60	45	-	64
A.D.L.	31	29	31	24

Sources: (1) Nefzaoui, 1979

(2) Alibes and Berge, 1983, results not published
(3) Ohlde and Becker, 1982

Paradoxically, screening therefore mainly decreases cellulose content while minimally reducing lignin content. This composition of olive cake cell wall constituents can be compared to that of cereal straws having an apparently high degree of lignification.

b. <u>Crude protein</u>

The content varies according to the type of olive cake (see Table 5) but remains relatively small. True protein nitrogen constitutes more than 95 percent of all nitrogen and has particularly low solubility (1.5 of total nitrogen according to Zelter, 1968, cited by Theriez and Boule 1970, and Gomez-Cabrera, 1983, (personal communication); 3 percent according to Nefzaoui, 1983). In addition, a large proportion of the proteins (80 to 90 percent) is linked to the ligno-cellulose fraction (ADF - N) (Nefzaoui, 1983).

c. <u>Fats</u>

Olive cake fat is high in unsaturated C16 and C18 fatty acids which constitute 96 percent of total fatty acids. Olive cake is highly vulnerable to air oxygen which is the main cause of spoilage of its organoleptic properties. However, Theriez and Boule (1970) observed that rancid olive cake oil does not seem to be the cause of the decrease in digestibility they observed <u>in vitro</u>, since the results obtained with olive cake accumulated during more than a year were the same as those of fresh olive cake.

The fat content of crude olive cake can be a major source of energy, but its contribution to the energy supply in exhausted olive cake is small.

2.4 Factors capable of affecting digestive utilization of olive cake

Many experiences have shown “poor digestive utilization” of olive cake. This may be caused by decreased activity of the rumen microflora which (measured by gas release) may decrease by 40 percent after ingestion of crude olive cake (Theriez and Boule, 1970). The ammonia production of sheep rumen liquor receiving olive cake also confirms decreased activity of the rumen microflora (Balti, 1974, Nefzaoui and Abdouli, 1979, Nefzaoui et al 1982).

Three hypotheses may be advanced to explain this:

2.4.1 Influence of fat content (especially for non-exhausted olive cake)

High concentrations of free fatty acids in the rumen can alter digestion and appetite. Fat can act through one or all of the following factors:

- **quantity: ruminants are sensitive to intake of fat above 5 percent of dry matter in the ration (Buysse, 1962);**
- **the nature of these fatty acids: Zerawski et al (1965) found that a proportion of 90 g per 24 hours of a C16 and C18 fatty acid mixture (content of which is high in olive cake) leads to about a 5 percent decrease of released methane:**
- **eventual products of oxidation whose toxicity may be dangerous, but in vitro digestibility of fresh and one year-old crude olive cake is the same according to Theriez and Boule (1970).**

2.4.2 Inhibiting factors

These could be simple phenol type compounds which would inhibit fermentation, or more complex ones of a tannin type which would insolubilize the proteins in the diet or in the olive cake itself (Theriez and Boule 1970).

Nevertheless in general the results cited in the bibliography refer to the fruits before the oil is extracted, whereas this operation eliminates large quantities of polyphenols and tannins in the vegetation waters.

Analyses of olive cake by Nefzaoui (1978) showed that tannin rates below 1 percent, were not sufficient to act as a depressant on rumen microflora and on the digestibility of protein; and polyphenol levels between 0.15 and 0.75 percent of dry matter are not sufficient to inhibit fermentation.

2.4.3 Influence of lignin

Olive cake is particularly rich in lignin and poor in cell content. It seems there is the same phenomenon of "protection" of carbohydrates related to lignin as occurs with straw. In fact, when olive cake was treated with alkalis its in vitro digestibility was almost four times higher (Nefzaoui, 1983).

2.5 Nutritive value of olive cake

2.5.1 Digestibility

First, it should be recalled that in case studies of certain by-products of the olive cake type, a number of researchers (Michalet-Doreau, 1981, Orskov, 1977, and Preston et al, 1981) showed the importance of the degree of participation of this feed in the total diet, type of associated feeds (fodders, concentrates), level of animal feeding, and, lastly, method of calculating or

estimating digestibility.

There are few studies on olive cake digestibility and the results are very heterogeneous. Table 7 gives the main results of in vivo digestibility obtained with different types of olive cake.

Table 7: Main results of in vivo digestibility of different types of olive cake

Type of olive cake	Method of determination	Dry matter	Organic matter	Crude protein	Ether extract	Crude fibre	Source
Fatty pulp	On sheep, by difference	-	-	21.6	85.6	0	Maymone et al, 1962
	On sheep, by difference (24% of the diet)		43.7	13.4	-	-	Theriez, Boule, 1970
	On sheep, by difference (15% of the diet)		57.4	66.8	90.0	-	Theriez, Boule, 1970
Exhausted pulp	On sheep, by difference (21% of the diet)	-	69.4	28.0	-	-	Theriez, Boule, 1970
Crude olive cake	In vivo on sheep	-	30,8	6,6	65,5	28,4	Kellner, 1924
	In vivo on sheep	-	-	-	86	0	Meade, Guilbert, 1927
	In vivo by difference on sheep	32.9	35.4	24.5	57.7	29.6	Boza, Varela, 1960
	-	-	26.2	10.0	89.6	-	Boza et al,

	-	-	31.0	9.0	89.2	29.6	Boza et al, 1970
	In vivo by difference on sheep	-	45.7	23.6	75.2	-	Theriez, Boule, 1970
Partly destoned fatty olive cake	On sheep, by regression	41.9	49.9	32.5	91.5	22.2	
							Ben Hamouda, 1975
	On sheep, direct	-	37.2	19.4	84.1	33.6	Maymone, Carusi, 1935
	On sheep, by difference	-	21.6	15.5	85.5	12.8	Maymone, Battaglini, 1962
Exhausted partly destoned olive cake	On sheep, by difference	-	-	10.1	67.9	11.1	Maymone et al, 1961
	On sheep, by difference	-	-	14.0	60.9	17.9	Maymone et al, 1961
	On sheep, by difference	-	-	46.0	56.0	28.0	Maymone, Carusi, 1935
	On sheep, by regression	43.0	54.4	35.9	-	36.4	Nefzaoui, 1978
	On sheep, direct	48.1	50.0	32.2	80.2	47.3	Nefzaoui, Abdouili, 1978
	On sheep, direct	30.5	32.2	38.8	81.8	22.5	Nefzaoui, 1980
							Nefzaoui et al,

	On sheep, direct	36.4	39.6	29.0	77.4	39.1	1982
	-		48.0	52.1	77.8	47.9	Eraso et al, 1978
	-	-	18.8	8.0	27.6	16.6	Eraso et al, 1978
	On sheep, by difference	19.1	-	25.4	88.9	27.0	Valamotis, 1983
	-	36.7	36.7	15.8	74.1	-	Accardi et al, 1979
	-	50.5	51.9	9.9	88.0	57.0	Duranti et al, 1978
		57.4	57.6	11.0	90.5	66.4	Duranti et al, 1978

It is sometimes difficult to classify accurately the type of olive cake concerned according to reports of experiments since experimental conditions are not always clearly defined, and they also correspond to different years, products of different origins, etc. Consequently it is often difficult to interpret the results presented in such reports.

Generally, however, we can conclude that:

- **dry matter and organic matter digestibility remains low (20–50 percent) regardless of the type of olive cake;**
- **fat always has a high digestibility (60 – 90 percent);**
- **on the average, crude proteins have a low digestibility (about 20–25 percent), although it**

varies widely;

- crude fibre has an estimated digestibility varying from 0 to 40 percent.

2.5.2 Intake

The available results are scarce and refer mainly to partly destoned exhausted or non-exhausted olive cake, (Nefzaoui, 1983, Boza et al, 1970, Eraso et al, 1978). Olive cake as such is not very palatable and is not widely consumed. Most of the tests described included an addition of 8 to 10 percent of molasses (sometimes 30 percent). In these conditions rations containing a smaller or larger proportion (20 to 83 percent) of olive cake are satisfactorily ingested.

- 85 to 130 g dry matter/day/$P^{0.75}$ or 1.4 to 2.2 kg of DM/day for sheep

2.5.3 Degradability

According to Nefzaoui (1983), since olive cake is rich in ligno-cellulose, it has a low degradability in the rumen and the maximum values reached are low (in the case of exhausted screened olive cake 32 percent of dry matter was degraded after remaining 72 hours in the rumen). Protein degradability is also very low, which may be due to the fact that 75 to 90 percent of the nitrogen is linked to the ligno-cellulose fraction, thereby resulting in low nitrogen solubility, which is only 2.3 percent (soluble N % total N) in the case of crude olive cake and about 0.2 to 0.4 percent in that of screened olive cake.

2.5.4 Biochemical characteristics in the rumen

The few existing data come from studies made in Tunisia by Nefzaoui (1979) and Nefzaoui et al

(1982) on exhausted screened olive cake.

- **Ammonia production is scarce when this olive cake is distributed freely to sheep. In fact NH3 production is below a minimum threshold of 50 mg/l or rumen liquor. In diets where 40 percent barley is replaced by 40 percent olive cake, NH3 production varies from 64 to 78 mg/l depending on the time the sample is taken.**

- **Intake of olive cake alone results in scarce production of total volatile fatty acid (51 mM/l). The proportion of the different Volatile Fatty Acids (VFA) (71 percent acetic, 19 percent propionic and 10 percent butyric) corresponds to a type of fermentation characteristic of rough feeds (straw, hay).**

- **The rumen liquor pH of animals fed on olive cake varies from 6.6 to 7.2 and is therefore favourable to optimum cellulolytic activity.**

2.5.5 Feeding behaviour

In its physical appearance exhausted screened olive cake (1 to 4 mm pellets) does not directly resemble rough fodders (straw, hay). However this type of olive cake provides perfectly normal rumination and intake identical with that of chopped hay (Table 8). This positive aspect of olive cake is due to its abundance of structural elements (high cell wall constituent and especially ligno-cellulose contents).

Table 8: Feeding behaviour of Texel breed sheep receiving exhausted screened olive cake (Nefzaoui et al, 1982)

	Chopped hay (1)	Hay pellets (1)	Olive cake (2)	Olive cake pellets (3)	4 %soda olive cake pellets (4)	3% NH_3 olive cake (5)

Intake duration, %	20.40	14.80	19.1	9.0	14.1	16.7
Rumination duration, %	32.90	6.10	36.4	30.4	28.8	32.1
Number of rumination balls,						
nbr/d	-	-	709.0	494.0	436.0	574.0
Duration of ball (seconds)	-	-	44.0	53.0	57.0	48.0
UID, min/g $DM_i/P^0.75$	-	-	3.2	1.	1.7	2.7
URD, min/g $DM_i/P^0.75$	-	-	6.2	3.8	3.4	5.2
Rumination unit ball						
(nbr/g $DM_i/P^0.75$	-	-	8.51	4.3	3.6	6.5

(1) According to Ruckebusch and Marquet, 1963
(2) Olive cake with 8% molasses and 100 g ground barley, consumption ad libitum (6 sheep,recording period, 12 days)
(3) Olive cake with 8% molasses and 1.5% urea then made into pellets. Distributed separ-ately, consumption ad libitum - Idem 2
(4) Olive cake previously treated with 40 g NaOH/kg - Idem 2
(5) Olive cake previously treated with 3 % ammonia - Idem 2.UID= Unitary intake durationURD=

Unitary rumination duration

2.6 Possibilities of improving nutritive value of olive cake

As in the case of straw, alkali treatments have received the most study.

2.6.1 Soda treatment

Small quantities of soda less than 4 percent, have only slight effect on in vitro digestibility of dry matter. The latter increases progressively, reaching levels of 50 to 70 percent for 6 to 8 percent quantities of soda, (Abdouli, 1979; Nefzaoui, 1979). Washing and filtering of olive cake to eliminate excessive soda decrease digestibility.

Treatment of fatty olive cake with soda can cause formation of soap by saponification. This phenomenon was also pointed out by Karalazos (1979). Therefore only exhausted olive cake must be treated or else alkalis (Na_2CO_3, NH_4OH), which do not provoke saponification reactions, must be used.

a. **Influence of treatment on chemical composition**

   Besides the predictable increase of ash content, the treatment modifies mainly the cell wall constituents (Table 9) and protein fraction contents linked to ADF.

Table 9: Average cell wall constituents of exhausted screened olive cake untreated or treated with 4 percent soda (6 percent 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
Hemi-cellulose	10.2	8.3
Cellulose	23.1	21.3
Total ADF-N/N, %	94.9	74.6

b. **Influence on digestive utilization:**

Degradability of proteins and dry matter improved. In vivo digestibility of dry matter, especially proteins and crude fibres increased. (Table 10).

Table 10: Influence of soda treatment (industrial processing) on in vivo digestibility of exhausted screened olive cake

Distribution method	**Treatment**	**Apparent digestibility coefficient**								
		DM	**OM**	**DCP**	**CF**	**NDF**	**ADF**	**ADL**	**H.C.**	**C**
Distributed separately, Thibar black rams(1)	Untreated	48	50	32	47					
	Treated 4% NaOH	52	52	43	55					
With molasses, as pellets distributed with 100 g hay and 1.5% urea, Texel sheep (2)	Untreated	31	32	39	23	24	18	14	49	26
	Treated 4% NaOH	35	36	46	33	33	26	23	62	29
40% olive cake, 49% barley, 8% molasses and 3% mineral concentrates, Thibar black rams (3)	Untreated	68	70	59	49					
	Treated 4% NaOH	74	75	65	61					
	Treated 4% NaOH									

	+ 1.5% urea	71	74	70	58					

(1) Exhausted screened olive cake with 26 percent CF, Nefzaoui A., and Abdouli, H., 1979.
(2) Exhausted screened olive cake with 14 percent CF, Nefzaoui, A., Marchand, S. and Vanbelle, M.1982.
(3) Exhausted screened olive cake with 26 percent CF, Nefzaoui, A., and Abdouli, H., 1979.

The already large intake did not increase. On the other hand, the animal's water consumption was more than doubled and urine excretion more than tripled.

2.6.2 Ensilage with alkalis

Micro-silo (1.5 1) studies showed considerable in situ improvement of digestibility with large doses of soda (8%) which was higher than that obtained with ammonia (Table 11).

Table 11: In situ digestibility of alkali-treated exhausted screened olive cake silage (Nefzaoui, A. et al, 1982)

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

2.6.3 Ammonia treatment

Exhausted screened olive cake with molasses added previously was stored in plastic bags with an injection of NH_3 (3%). The result was a considerable improvement of nutritive value (Table 12) especially through:

- **nitrogen enrichment (+ 200%)**
- **improved digestibility of all nutrients, especially proteins (+ 90%)**
- **increased nitrogen retention.**

Table 12: Digestibility, intake and protein balance of exhausted screened olive cake ensiled with ammonia * (Nefzaoui, A. et al, 1983)

	Untreated olive cake	**Treated 3% NH_3**
Digestibility (%)		
DM	36	41
OM	40	43
CP	29	55
EE	77	86
CF	39	49
NDF	32	39
ADF	25	32
ADL	13	19
Hemi-cellulose	60	63
Cellulose	43	49

Intake g DM/d/$P^{0.75}$	99	98
Protein balance: g N/d/$P^{0.75}$		
Ingested	1.903 (100%)	3.610 (100%)
Faecal	1.353 (71%)	1.632 (45%)
Urinary	0.240 (13%)	1.147 (32%)
Retained	0.310 (16%)	0.831 (23%)

*** Factorial cross-over experiment with Texel breed lambs receiving olive cake freely 100 gbarley per day.**

2.6.4 Ensilage of screened olive cake with poultry manure

Trials made by Nefzaoui and Deswysen (1982) showed that silages containing 70 percent of manure accumulated during less than 21 days and 30 percent exhausted screened olive cake were excellently preserved (according to the FLIEG's evaluation criteria).

2.6.5 Treatment with Na2 CO3

Vaccarino et al (1982) compared treatments with different doses of NaOH and Na2CO3 on partly destoned olive cake at 70° C during 150 minutes before adding solvent. Both methods improved digestibility in vitro considerably; however, soda proved the most effective (Table 13).

Table 13: Effects of treatment of partly destoned olive cake with NaOH or Na2CO3 on in vitro digestibility (Vaccarino et al, 1982)

		NaOH, %			**Na2 CO3, %**		

	Control	2.9	5.7	8.6	3.8	7.2	11.4
Digestibility of							
Org. Mat.	15.8	20.7	32.3	50.8	26.9	40.6	47.9
Digestibility of							
dry matter	9.7	8.8	27.2	31.9	5.1	39.4	46.5

2.6.6 Mechanical treatment

The only practical mechanical treatment consists of partly separating the shell of the kernel by screening or ventilation. This has the effect of markedly reducing the crude fibre (see Table 5) and true cellulose contents but, paradoxically, the lignin content (see Table 6) is reduced very little.

If we refer to Table 7, the effect of partial destoning on digestibility of non-exhausted olive cake is not clear; the results are so few and heterogeneous that no specific conclusions can be drawn from them.

However recent studies (Nefzaoui et al, 1983, unpublished results) comparing exhausted olive cake, unscreened, screened, or treated with different alkalis (Figure 5), showed that by itself screening improved:

- **digestibility of organic matter by 10 to 15 points, or in slightly lower proportions than soda or ammonia treatment but higher than those with Na2CO3 and urea;**

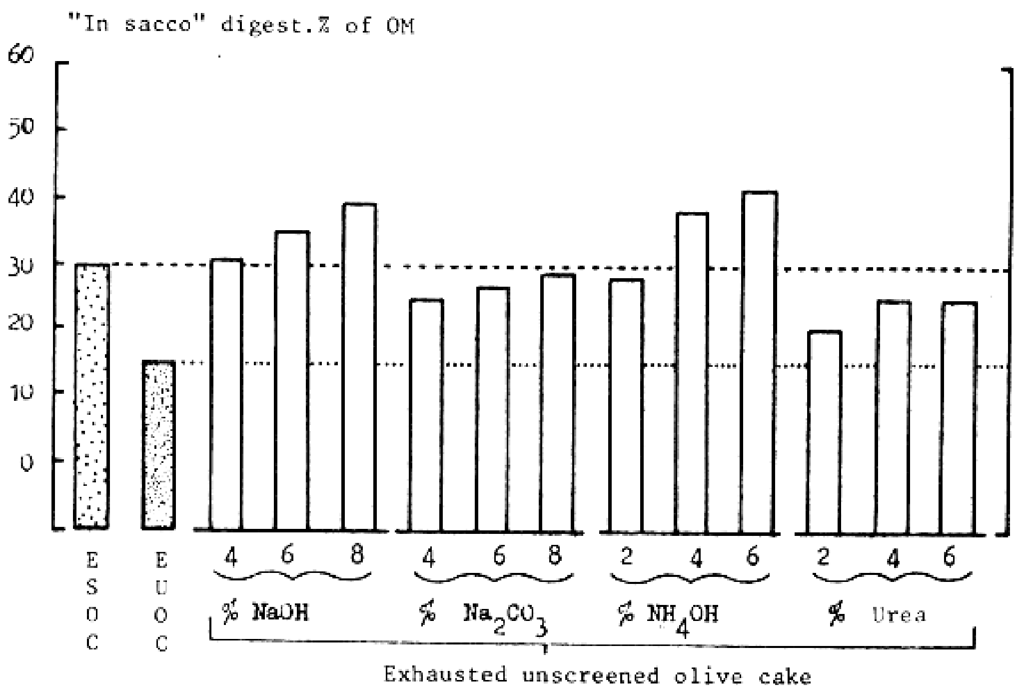
- **digestibility of protein to the order of 30 points, or markedly higher than all other treatment.**

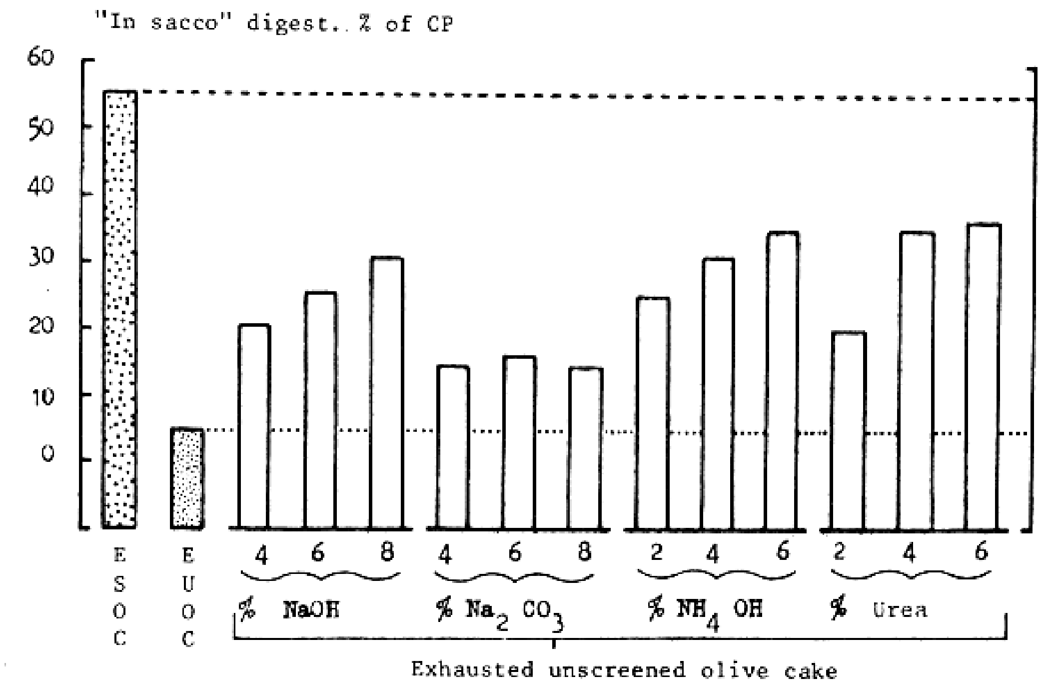
Therefore screening seems to be a very effective treatment for improvement of the nutritive value of exhausted olive cake.

2.6.7 Biological treatment

Very few experiments have been conducted in this field. However Karapinar (1977) and Worgan (1978) reported that the tissues contained in olive cake are resistant to microbial degradation. Fungi cultures on the olive cake have not noticeably decreased fibre content even after alkali treatment. Sporotriclum pulverulentum culture on screened olive cake increased crude protein content but did not significantly decrease that of crude fibre (Table 14

Figure 5: Effect of screening exhausted olive cake compared to various alkali treatments (Nefzaoui et al, 1983)





ESOC: Exhausted screened olive cake
EUOC: Exhausted unscreened olive cake

Table 14: Action of fungi (S. pulverulentium) on olive cake

Treatment	Yield: g/100 g by-product		Composition	
	Dry matter	CP	CP	Crude fibre
Olive cake	100	7.3	7.3	42
Crushed olive cake screened	51	4.8	9.4	21
Fungi culture	43.5	6.3	14.5	20.7
Fungi + alkaline treatment	34	8.5	25	15

Sources: Karapinar (1977); Worgan (1978)

Cited by Zoiopoulos, 1983 a,b,c,d

2.7 Use of olive cake in animal feeding

Olive cake in its different forms is traditionally used in most producer countries. Curiously, few thorough studies have been conducted to evaluate the effect of including it in varying degrees in animal diets.

2.7.1 Crude olive cake

This is used in Tunisia mixed with bran or even cactus to feed dromedaries most of the year or sheep during difficult seasons. But very few tests have been made with this type of olive cake.

2.7.2 Partly destoned fatty olive cake

a. on sheep: Bloemeyer (1977), distributing a concentrate containing 0 to 40% olive cake with urea-molasses obtained weight gains of 125 to 101 g/d with grazing sheep receiving 500 g of hay and the concentrate according to liveweight (20–30 g/kg liveweight).

   Ben Hamouda (1975) replacing 0 to 30 percent barley by olive cake in sheep diets obtained growths that were about the same, although slightly decreasing (274 g/d to 226 g/d) but with a higher conversion rate.

   Accardi et al (1979) replacing 30 percent of Sulla hay by 30 percent of olive cake in a lamb ration including 38 percent maize and 30 percent soya cake obtained slightly lower growths (191 g/d compared to 209 g/d) and a higher conversion rate (4.91 compared to 4.24).

   In Sardinia, Piccarolo and Paschino (1978), Paschino and Piccarolo (1980), Dattilo (1980),

and Dattilo and Congiu (1979) introduced screened olive cake (about 20 percent) in pellets containing various other by-products and reported ewe milk outputs comparable to those obtained with grazing.

Giouzelgiannis et al (1978) introducing 15 to 25 percent of olive cake (Kourgi method) in the lamb ration discovered no significant differences in terms of weight gain, intake or carcass quality; only the conversion rate was at a 25 percent higher level with olive cake.

b. on cattle: Experiments conducted in Italy (Piccinnini, 1906; Gugnoni, 1920; Maymone and Guistozzi, 1935 a and b) seem to show a positive effect of olive cake on the fat content of cow's milk with practically equal milk production (at 4% fat) when the cows receive 1.8 to 4 kg of olive cake/day.

In Greece Belibasakis (1982) feeding dairy cows with proportions between 10 and 20 percent of olive cake in the concentrate found no significant differences in milk production and composition.

Maymone and Giustozzi (1935), using heifers weighing 295 kg fed during 60 days with hay and lucerne silage, adding maize or olive cake meal (with 8 percent fat), obtained respective weight gains of 630 g/d (with 922 g/d of maize consumed) and 370 g/d (with 775 g/d of olive cake consumed).

2.7.3 Partly destoned exhausted olive cake

a. On sheep

This olive cake was used in “shortage periods” rations in Tunisia by Nefzaoui and Ksaier (1981), who incorporated 0–35 or 70 percent of it in concentrate distributed with 300 g/d of

straw to ewes which were first pregnant and then nursing (Table 15), during a period of 17 weeks. The performances of the ewes receiving 35 percent of olive cake were comparable to those of the control animals. Those receiving 70 percent had a 20 percent weight loss; weight of lambs at birth was lower and mortality was much higher (61 percent compared to 29 percent). However it must be mentioned that this ration not only enabled the mother ewes to survive but also made it possible to save a considerable number of lambs during a period of more than four months.

Table 15: Maintenance of pregnant ewes from mating to parturition in central Tunisia (Ousseltia) with rations based on exhausted screened olive cake (Nefzaoui, A., Ksaier, H., 1981)

	Control animal	**35% olive cake**	**70% olive cake**
Composition of rations (%)			
Olive cake	0.00	35.00	70.00
Bran	70.00	35.00	0.00
Molasses	26.00	26.00	26.00
Urea	2.00	2.00	2.00
Minerals	2.00	2.00	2.00
Performances			
Number of animals	20	20	20
Initial weight, kg	52.35	52.15	52.45
Final weight, kg	57.30	57.33	42.77
Weight of lambs at birth	3.50	3.30	2.60
Intake g DM/d/$P^{0.75}$	76.00	105.00	85.00

(1) Ewes belonging to the Barbarine breed, average age 6 years.
(2) The animals receive 300 g/d of straw and rations ad libitum.

b. On cattle

With young growing cattle, replacement of oat-vetch hay of poor quality by 0-20-40-60 percent of exhausted screened olive cake led to a steady decrease of weight gains which were 536-260-190-39 g/day respectively, (Bougalech, 1980). In this case too as high a proportion as 60 percent of this type of olive cake in the ration was able to ensure maintenance of the animals.

In Lybia, O'Donovan (1983), using 32 Holstein heifers weighing 284 kg receiving straw ad libitum (5.7 kg/d) and 2.7 kg of a concentrate containing 0-15-30-45 percent of partly destoned olive cake obtained no difference in weight gains, which were 688-706-695 and 698 g/d respectively. In another experiment 12 Holstein heifers and 12 Holstein bull calves weighing 130 kg and receiving a minimum of straw (0.6 kg/d) and 3.3 kg of a concentrate containing 0-15-30 percent of olive cake had respective increases of 1 029, 975 and 813 g/d.

2.7.4 Alkali-treated partly destoned exhausted olive cake

Treatment of exhausted screened olive cake with soda can improve digestibility (see paragraph 2.5.1).

Table 16: Fattening of Barbarine breed sheep with screened olive cake untreated or treated with soda (Nefzaoui, A. and Abdouli, H., 1979)

	Control	40% untreated olive cake	40% olive cake treated with 4% NaOH	40% olive cake treated with 4% NaOH+ urea

Composition of rations				
Untreated olive cake	-	40.00	-	-
Olive cake treated with 4% NaOH	-	-	40.00	40.00
Barley	89.00	49.00	49.00	47.40
Molasses	8.00	8.00	8.00	8.00
Urea	-	-	-	1.60
Minerals + vitamins	3.00	3.00	3.00	3.00
Performances				
Initial weight, kg	41.94	37.49	37.64	36.78
Final weight, kg	54.18	49.31	52.09	51.04
ADG, g/day	175.00	169.00	206.00	203.00
Intake, g DM/d/$P^{0.75}$	89.00	109.00	108.00	110.00
Consumption index kg DM/kg gain	9.29	10.94	9.04	9.24

(1) Each lot consisted of 10 male sheep aged 15 to 16 months.
(2) The animals received 200 g of Oat-vetch hay per day and concentrates ad libitum.
(3) The duration of the trial was 90 days.

Although replacement of 40 percent untreated olive cake in the concentrate distributed ad libitum to sheep also receiving 200 g/d of hay did not change their growth, the 4 percent soda treatment allowed increased weight gains and improvement of the conversion rate. This result was unchanged for the addition of urea (Table 16). However the differences were not striking.

This may be because the proportion of olive cake remained low,_i.e., 40 percent of the ration; the rest of the ration was very rich (about 50 percent barley and 8 percent molasses), and the proportion of soda-only 4 percent-was probably too low (see para. 2.6.2). In present economic circumstances it is unlikely that this soda treatment could become profitable by such a slight improvement of performance.

2.7.5 Other prospects

The plans for treatment of olive cake for furfural production in Tunisia, and probably in other countries, should lead to an increase in the proportion of partly destoned exhausted olive cake. It would be possible (and desirable) to carry out such destoning in the extraction plants rather than in the furfural plants. This would lower transport costs and keep the olive cake nearer the stock-raising areas, thereby making it more readily available to stock-raisers.

2.8 Conclusions

1. **Olive cake is a rough ligno-cellulose feed because of:**
   - **its high fibre (NDF), ADF and lignin contents;**
   - **its low crude protein contents;**
   - **the poor digestibility of its dry matter and crude protein;**
   - **its acetic type of fermentation in the rumen;**
   - **the feeding and ruminating behaviour of animals consuming it.**

2. Olive cake probably contains no toxic or inhibiting substances. Its poor digestive and metabolic utilization is probably due mainly to its high degree of lignification and to the tech nological process for oil extraction in which it is frequently subjected to high heat.

3. Distributed alone:

    - it is not palatable (on the other hand the addition of 8–10% molasses can result in a high intake level);

    - it causes weight losses in the animals;

    - it is poorly digested;

    - it causes low ammonia and volatile fatty acid production, a proof of its low nutritive value.

4. The tegument and shells have low digestibility. Screening, which eliminates part or all of the stones, improves the nutritive value of olive cake. Intensive screening, leaving only a very light product consisting mainly of the tegument would have the opposite effect. The screening operation should retain fragments of the crushed kernel which are especially rich in proteins and have high digestibility.

5. Its use without any previous treatment can ensure:

    - Normal performances (lamb fattening) when incorporated at levels below 30 or 40 percent and with sufficient proteins and minerals added;

    - Maintenance or survival of cattle in difficult conditions when incorporated at higher

levels (70 percent).

6. **Treatment can improve the nutritive value of olive cake:**

   a. **Development of industrial treatment with soda in spite of some improvement is still limited since the investments involved are high.**

   b. **Treatment with 6 to 8 percent doses of soda through ensilage would be effective but also too costly.**

   c. **Ammonia treatment (ensilage) would be more promising, since it would improve digestibility and provide an additional protein supply.**

7. **Supplementing olive cake by a good quality and low cost protein source would undoubtedly be profitable. Initial trials with poultry manure seem promising.**

8. **Table 17 sums up the possibilities of using olive cake in animal feeding. From the present state of information it seems that all types of olive cake can be used ad libitum without risk for survival operations, but none of them can provide for an intensive type of production.**

Table 17: Possibilities of using different types of olive cake in animal feeding.

Type of Production / **Type of olive cake**	**Survival**	**Maintenance**	**Moderate production level**	**Intensive production**
Exhausted olive cake	ad lib+			
	fodder + …	-	-	-
	ad lib+	ad lib+		

Crude olive cake	fodder + …	fodder + …	-	-
Fatty screened olive cake	ad lib+	< 30%	< 30%	-
	fodder + …			
Exhausted screened olive cake	ad lib+	ad lib+		
	fodder + …	fodder + …	< 40–50%	-
Pulp	idem screened fatty olive cake			

9. **One can find practically no experiments on pigs except that of Maymone and Durante (1945) who replaced 50 percent of maize in a concentrated ration containing 70 percent maize and obtained respective weight gains of 940 g/d with 70 percent maize and 770 g/d with 50% of partly destoned fatty olive cake (20 percent EE) and 20 percent maize during a period of 64 days with pigs weighing about 16 kg at the start. However these results have not been confirmed subsequently by other experiments and are hard to interpret in view of the lignocellulose content of olive cake.**

CHAPTER III: OLIVE LEAVES AND BRANCHES

The use of olive tree leaves and branches in animal feeding can encounter a number of problems which Alibes and Berge (1983) summed up as follows:

a. **leaves and branches are scattered over the land**
b. **cattle are not always near olive plantations**
c. **for reasons of plant pathology, it may be necessary to eliminate branches from the olive plantations quickly**
d. **transport costs increase the final cost**
e. **preservation of leaves presents problems**
f. **the feeding value of the final product is low**

However, leaves and branches are traditionally used fresh in many countries and can be a substantial fodder resource.

3.1 Physical characteristics

There is no specific identification of olive tree branches distributed for feeding ruminants. However in the specialized literature they usually seem to be referred to as branches of less than 3–4 cm in diameter.

However, one must distinguish between leaves collected at the oil mill (para. 1.4.1) which have a small proportion of wood, and branches on which the proportion of wood can be considerable. According to Civantos (1981 a and b), on branches less than 4 cm in diameter the proportion of leaves is about 50 percent.

In most countries pruning wood is given freely to animals who obviously prefer to eat leaves and small twigs in proportions which are hard to determine. In Spain large scale work has been conducted for collecting and conditioning pruning wood with special machines (Civantos, 1981

b and 1982; Parellada et al, 1982) which also allow separation of the leaves from the wood.

3.2 Preservation

Since harvesting and pruning are seasonal, it may be useful to consider preservation of leaves and branches so as to spread consumption over a longer period. Two methods can be used, i.e. drying or ensilage.

For leaves collected at the oil mill, Nigh (1977) compared preservation by air drying and by ensilage. Manual air drying decreases the bitterness of the leaves and produces an odour like that of fresh hay. However leaves should not be dried too much because then they lose their palatability. However this method requires a great deal of attention and work and is difficult to apply. Ensilage in vertical silos without preservants also removes the bitter taste but the quality of the product has proved to vary considerably depending on conditions of execution. Nevertheless the ensilage method has seemed preferable to drying. It should be pointed out, however, that a simple stock silo would certainly afford as good a preservation as a costly vertical silo.

Maymone et al (1950) obtained a satisfactory silage (PH = 4.2 for 23 percent DM); nevertheless leaf and branch ensilage tests made in Spain by Vera and Vega and Galan Redondo (1978), even using preserving substances, has apparently produced poor results. Parellada et al (1982) have also described different forms of ensilage (some of them including moist materials); however the available data are incomplete. According to Alibes and Berge (1983) doubts are raised as to the feasibility and usefulness of ensiling this type of harvest residues due to the following factors:

a. their high dry matter content;

b. **their low density and the difficulty of eliminating oxygen sufficiently by stacking them;**
c. **insufficient fermentable sugars;**
d. **the structure of the product (since the wood pierces the plastic sheeting covering them).**

Lastly, the fact must be seriously considered that Mediterranean olive plantations are located in dry climates and consequently natural drying would seem to be the most logical method.

As has been mentioned previously, large-scale work has been undertaken in Spain for collection and separation of leaves in dry form. This mechanized method is still costly but deserves further study.

The branch-lopping operation should not be delayed more than 8 days after pruning in order to prevent loss of the leaves. In normal conditions (absence of rain), between time of cutting (when leaves contain 50 percent dry matter), piling, lopping of branches, transport and separation of leaves from branches by ventilation, a dried state can easily be obtained sufficient for good preservation (87–92 percent DM). The leaves can then be conditioned to obtain higher densities and decrease transport costs (Parellada and Gomez-Cabrera, 1983).

3.3 Chemical composition

The chemical composition of leaves and branches depends on many factors (olive tree variety, agro-climatic conditions, season when the sample was taken, and lastly, the different treatment applied).

Table 18: Indicative chemical composition of olive tree leaves and branches

By-product	Dry matter	Organic matter	CP	Crude fibre	EE	NDF	ADF	ADL
Green branch	68	90	7.7	24.5	11.2	-	-	-

Dry branch	87–92	91.5	7–9	23–29	6	-	-	-
Green leaves	50–58	95	11–13	15–18	7	47	28	18
Air-dried leaves	95	95	7–11	13–23	5	40–45	28–35	18
Leaves with								
8.8% wood	87	92	7.7	19	-	48	34	19
Leaves with								
11.4% wood	93	92	8.7	19	-	-	-	-
Leaves with								
15% wood	74	95	6.7	30	-	56	44	19
Leaves with								
22.6% wood	93	92	7.8	21	-	51	35	18
Leaves ensiled								
with 8.8% wood	46	91	7.7	-	-	-	32.5	19

Source: Adapted from Alibes and Berge, 1983; many sources cited.

In general these different by-products have relatively homogeneous and well-defined characteristics:

- **the dry matter in green leaves comes to about 50 percent, that in dry leaves about 90 percent;**
- **their total crude protein content is low, i.e. 7 to 8 percent in dry or ensiled leaves, slightly higher in green leaves;**
- **their ether extract content of about 6 percent is higher than that of traditional fodders;**

- **their crude fibre content is variable and relatively small;**
- **their cell wall constituents increase considerably with wood percentage, especially lignecellulose contents lignin level seems to be stable at 18 to 19 percent.**

The crude protein content seems to be less in branches than in green leaves and is comparable to that of dry leaves. Naturally the crude fibre content is markedly higher than that of leaves.

3.4 Nutritive value of leaves and branches

3.4.1 Digestibility

The first tests made in Italy (Maymone et al, 1950) showed that drying and ensilage of olive tree leaves caused a considerable decrease in the digestibility of dry matter, organic matter and crude protein (Table 19)

Table 19: Coefficient of in vive digestibility of olive leaves according to preservation method (from Maymone et al, 1950)

Conservation	Dry matter	Organic mat.	Crude protein	Crude fibre	Ether extract
Fresh	60	61	44	29	25
Dried	43	45	24	25	29
Ensiled	46	48	17	39	42

More recent studies conducted mostly in Spain to measure digestibility of different types of leaves and branches are summarized in the following table:

Table 20: Coefficient of digestibility of different types of olive tree leaves and branches

By-product	Dry matter	Organic mat.	Crude protein	Crude fibre	Ether extract
Green branch	57	60	32	46	51
Dry branch	52	55	13.5	27	16
Green leaves	54 *	-	-	-	-
Air-dried leaves	54 *	47 *	-	-	-
Leaves + 8.8% wood	36.5	39	< 0	-	-
Leaves + 11.4% wood	47.2*	-	-	-	-
Leaves + 15% wood	-	42	7	36	29
Leaves +22.6% wood	30.5	32	< 0	-	-
Leaves ensiled with					
8.8% wood	40*	29.5	< 0	-	-

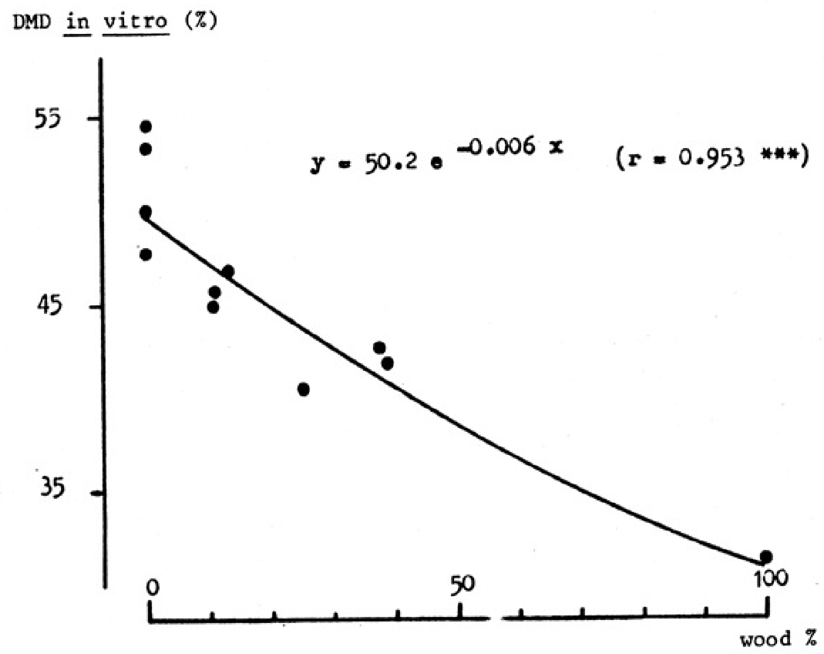
*** In vitro digestibility; in other cases: in vivodigestibility.**

Source: Adapted from Alibes and Berge, 1983; many sources cited.

The digestibility of dried branches compared to green branches seems slightly lower for dry matter and organic matter and much lower for crude protein.

The results obtained in vitro on green or dried leaves may have been distorted by the fact that the green leaves should have been oven-dried before evaluation since the substantial differences obtained by Maymone et al (1950) were not found in them. On the other hand, the influence of the proportion of wood combined with the leaves was reflected by a marked decrease of digestibility. This is shown clearly in Figure 6. Moreover, in vivo digestibilities of crude protein are very low and even negative.

Figure 6: Evolution of in vitro digestibility of olive branch dry matter according to wood percentage (Alibes et al, 1982)



3.4.2 Intake

Olive tree leaves distributed fresh during the winter season are usually consumed willingly by animals without any problem of adaptation, even over a long period.

However station experiments made sometimes had very different results. For example Boza et al (personal communication) working with goats in metabolic cages obtained voluntary intakes of:

- **80 g DM/kg$^{0.75}$ with fresh leaves**

- 71 g DM/kg$^{0.75}$with dried leaves

Whereas Alibes et al (1982) and Gomez-Cabrera et al (1982), using dried leaves (more or less contaminated) on sheep obtained intakes of 42 g and 23 g DM/kg$^{0.75}$ respectively

Some authors (Gomez-Cabrera et al, 1982) reported problems of twig accumulation with unseparated dried leaves in the third stomach of cattle. However no such problem was observed with separated leaves.

Distributing dried leaves ad libitum Gomez-Cabrera et al (1982) increased the intake from 23 g to 45 g/DM/kg 0.75 when they added a sunflower meal supplement. Alibes et al (1982) also observed increased intake when olive leaves distributed to sheep were supplemented with 18 percent barley and 1.5 percent urea in the ration.

3.5 Treatment to improve nutritive value of leaves and branches

3.5.1 Mechanical treatment

In the light of the results shown in Figure 6 it seems clear that separating the leaves from the wood constitutes a very effective treatment for improving digestibility of olive tree branches. Work now being done in Spain should lead to development of practical methods that can be applied on the farm.

3.5.2 Alkali treatment

Tests of alkali treatment of dried leaves by Alibes et al (1982) have mostly been disappointing (Table 21). In the case of soda treatment the effect on digestibility has even proved negative.

These authors believe that with this type of fodder, containing less than 50 percent of cell wall constituents and about 20 percent lignin, the action of the soda could not be as effective as on cereal straw (containing 80 percent cell wall constituents and less than 10 percent lignin).

With anhydrous ammonia treatment, in spite of an increase of about 10 percent in crude protein, the effect was not more noticeable either on digestibility or on the sheep intake level.

Table 21: Effect of alkali treatment on nutritive value of dried olive leaves (Alibes et al, 1982)

	Dried leaves	**Ensiled leaves with water**	**Ensiled leaves with 4% NaOH**	**Leaves treated with NH_3**
Dry matter, %	87.0	45.7	44.8	83.3
Total crude protein DM	7.7	7.7	6.2	16.8
NDF	47.8	-	-	-
ADF	33.9	32.5	32.4	29.5
ADL	19.1	18.6	16.7	15.8
DM in vitro digestibility	45.2	40.0	43.0	47.8
OM in vivo digestibility with				
sheep	40.6	29.5	38.5	42.1
g DM/kg 0.75/d intake with				
sheep	41.7	48.5	47.7	48.9

In Italy, Martilotti and Danese (1983) also compared the effect of alkali treatments on olive

branches crushed and preserved during 60 days in 25-litre plastic recepticles. The results shown below are somewhat more promising.

Table 22: Effect of various alkali treatments on digestibility of crushed olive branches (Martilotti and Danese, 1983)

	Untreated branches	**+4.7% NaOH**	**+5.2%NaOH +1.5% NH_3**	**+2.5% NH_3**
Dry matter %	62.6	59.5	60.2	61.5
Total crude protein matter	5.9	6.5	14.1	16.9
Crude fibre	29.4	25.5	23.7	28.1
NDF	58.1	52.7	47.6	55.9
ADF	44.8	40.6	37.7	43.7
ADL	16.0	13.8	14.4	15.5
DM in vitro digestibility	35.3	40.6	49.5	47.5
OM in vitro digestibility	36.4	44.2	52.7	48.7

The effect on in vitro digestibility of treated crushed olive branches was very positive, especially when ammonia and soda were used together, as the effect of ammonia seemed to be greater besides considerably increasing the digestible crude protein content.

The same authors repeated this experience, treating 5–6 ton stacks of crushed branches enclosed under a polyethylene sheet with two doses of anhydrous ammonia during 40 days.

The results are summed up in the table below:

Table 23: Effect on digestibility of olive branches treated with anhydrous ammonia (Martilotti and Danese, 1983)

	Untreated branches	+2.5% NH_3	+4.5% NH_3
Dry matter	62.3	62.2	62.1
Crude protein	7.9	16.7	23.8
NDF	58.1	54.5	50.9
ADF	44.8	42.1	38.6
ADL	16.0	15.0	14.6
DM in vitro digestibility	35.3	42.9	45.1
OM in vitro digestibility	36.4	44.3	47.7

These results obtained in conditions which can be reproduced on the farm seem highly positive and comparable to those obtained previously in the laboratory.

3.6 Use of leaves and branches in animal feeding

As has been mentioned previously leaves and branches are traditionally distributed to animals either at the trough or in the field in olive-producing regions. It is difficult to estimate the percentage reserved for this use and it varies considerably from one country to another. In any case, ad libitum distribution ro ruminants presents no special problems except that of the low nutritive value of this fodder.

Very few real experiments have been conducted in this field. Nigh (1981) reported that at the Kolymberi Centre in Crete olive leaves collected at the oil mill were distributed fresh (less than 2 days old) at a rate of 15 kg/day to Holstein cows. Zoiopoulos (1983a) observed that the distribution rate of such fresh leaves now comes to 30 kg/d in two meals. Similar quantities are distributed in silage form after the harvesting season. Although specific scientific control trials were not made, the author mentioned that there was a positive effect on milk production. Fresh

leaves are also distributed sometimes to sows.

Fresh leaves and twigs were distributed to sheep and goats in Greece at rates of 6 percent of liveweight as the only fodder, and up to 10 percent to rabbits (Kalaisakis, 1975). However Zoiopoulos (1983a) suggests that for ruminants the optimum level would be 2.5 percent of liveweight.

In Spain Muñoz et al (1983), studying ad libitum rations of dried leaves distributed to lambs weighing 36 kg, with a supplement of barley and added fishmeal protein (230 g/lamb-day), obtained weight gains of 77 g/d compared to only 40 g with urea, while the control lot receiving lucerne hay and 200 g barley obtained a weight increase of 154 g/d in a period of 90 days.

For dried leaves, Alibes et al (1982) recommend utilization comparable to that of poor/ quality roughage such as straw, that is, with a protein supplement, a small readily fermentable energy supply, and a mineral supplement.

The situation would be more advantageous with fresh leaves, especially for goats (Boza et al, personal communication).

3.7 Conclusions

To sum up, it can be assumed that digestibility of organic matter is acceptable with fresh olive leaves compared to average quality fodders. However, with dried leaves the quality decreases and becomes comparable to that of cereal straw. When the wood percentage is relatively high the value decreases even further becoming lower than that of ordinary cereal straw.

The protein value of fresh leaves is very low and of dried leaves practically none.

Intake levels remain relatively low but can be improved by a small addition of protein and energy supplement.

Mechanical treatment allowing separation of leaves from wood markedly improves their use as feed.

The few experiments with alkali-treated dried leaves have had no significant effect, whereas with olive tree branches collected fresh and alkali-preserved a marked improvement of in vitro digestibility has been observed.

Unfortunately, few animal feeding trials have been made to be able to judge statistically the effects of incorporation of olive leaves and branches in rations on animal production (milk or meat). But their use presents no practical problem.

In any case, to achieve production levels, it would seem that a rational use of olive leaves and branches according to their location and nutritive value would be to make up rations where they are freely distributed to animals supplemented with grazing fodders or other locally available fodder resources.

Animal and olive production should therefore be integrated as has been done traditionally in many regions of the Mediterranean Basin. Such integration would be profitable to both the animal and plant sectors. The animals would valorize by-products which constitute a low-cost feed but which would otherwise be wasted, while olive plantations in turn would receive the benefits of an organic fertilizer of which their soils are often badly in need.

CHAPTER IV: VEGETATION WATERS

4.1 Physical characteristics

Vegetation waters have the appearance of a brown watery residue liquid. The liquid has a pleasant odour but a bitter taste. This effluent, which has relatively high organic matter content, constitutes a source of pollution which creates a serious problem for the olive industry.

4.2 Chemical composition

Vegetation waters have the following composition:

Table 24: Olive vegetation water chemical composition

water	83.5% (1)	83.0% (2)	88% (3)
organic matter	14.7%	15%	10.5%
ash	1.8%	2%	1.5%
crude protein	2–8%	2.4%	1.25%
ether extract	0.03–0.8%	1.0%	0.1%
polyphenols	-	1.5%	1.0%

Source: (1) Codounis, 1973;
(2) Cucurachi, 1973;
(3) Fiestas Ros de Ursions, 1981.

Their relatively high polyphenol content is a drawback for animal feeding (antitrypsic action).

Chemical composition varies according to many factors, particularly the oil extraction method.

4.3 Possible use in animal feeding

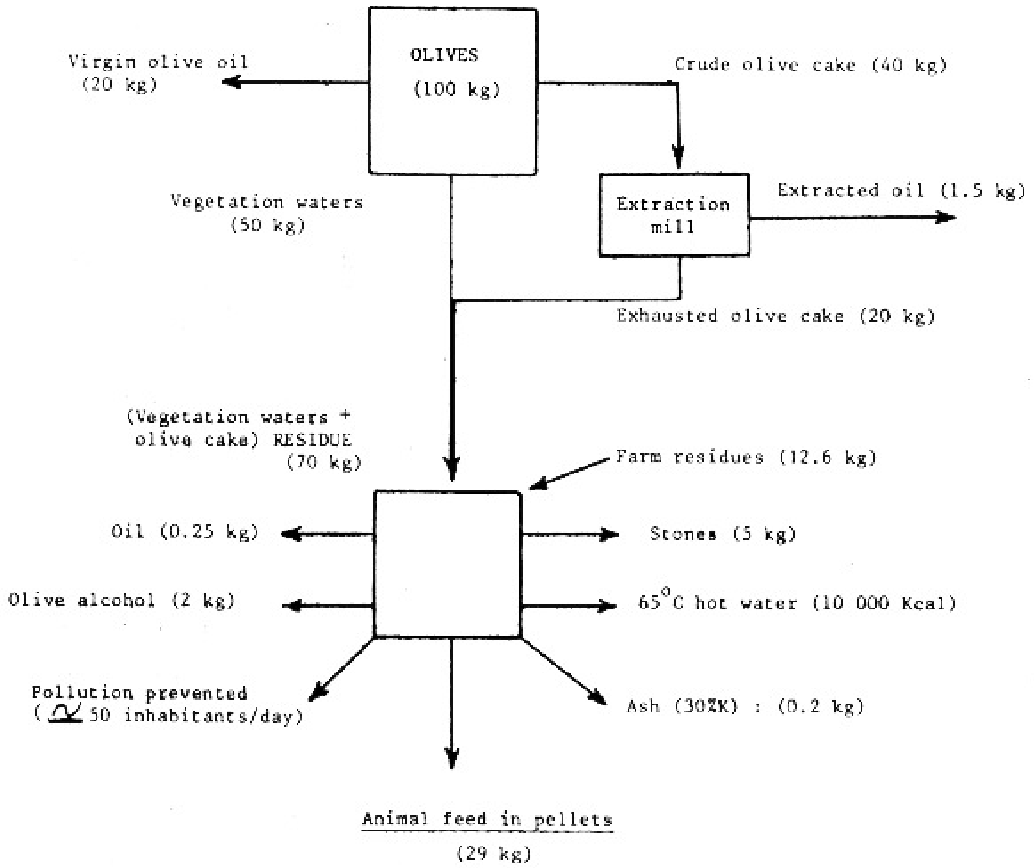
The documentation on this subject is too scarce. However, Martilotti (1983) has described a method which could prove useful in certain conditions and which has now been developed in Italy (Dalmolive method, Figure 7).

The method combines approximately:

- **50 kg vegetation waters**
- **20 kg partly destoned exhausted olive cake**
- **12.6 kg of several agricultural residues and by-products**

which can produce 29 kg of feed in pellets whose chemical composition is as follows:

Figure 7: Dalmolive method



Source: Martilotti, 1983

Table 25: Chemical composition of vegetation water paste obtained by the Dalmolive method

	Italy (1)	**Greece (2)**
Dry matter :	85.3%	93.6%
Crude protein :	21.6%	21.8%
Ether extract :	4.0%	3.3%
Crude fibre :	13.1%	4.7%
Ash :	8.9%	9.5%

Nitrogen-free extract :	52.5%	60.7%
Digestible crude proteins :	17.2%	-

Source: (1) Agricultural chemistry laboratory of Milan
(2) From Zoiopoulos et al (1983)

Bufano et al (1982) conducted a feeding trial using 18 month old ewes receiving hay and a mixture containing 0–20–40 or 60 percent vegetation water paste (moisture content varying from 35 to 57 percent), straw or crushed olive branches, and a 20 percent protein supplement. The results obtained were very unsatisfactory (Table 26). Average daily liveweight gains were low for all the lots during the entire experimental period and did not seem to vary with different rations. However they showed that vegetation water paste was accepted willingly and that rations containing up to 34 percent of the total (60 percent of the mixture) with low nutritive value fodders such as straw or olive branches, hay, and a protein supplement (about 11 percent of the total ration) would at least ensure maintenance of the sheep and even a slight liveweight increase.

Several tests have been undertaken for production of single cell protein from vegetation waters (cited by Zoiopoulos, 1983a). However this method does not seem to be feasible in present production and economic conditions.

Lastly, the direct use of vegetation waters as drinking water for livestock was tested at the Food Oils and Fats Experimental Station in Milan. These waters were suggested to replace drinking water for hens and turkeys (Fedeli and Camurati, 1981). In the case of turkeys it was estimated that the cost of a kilo of meat produced was lower if vegetation waters were used, and a marked decrease of mortality rates was also observed. However the authors do not provide statistical data.

4.4 Conclusions

Studies on the nutritive value of vegetation waters and possibilities for their use in animal rations are too few to be able to draw accurate conclusions at present. It would certainly be worth undertaking new experiments on vegetation water paste obtained from the Dalmolive method. The use of vegetation water in other ways, for example as drinking water for turkeys, and probably ducks, could also be the subject of new investigation, but would have only a small impact on the quantity of vegetation waters used.

Table 26: Feeding of 18-month old ewes with a mixture containing 0 to 60 percent vegetation water paste straw or olive branches, 20 percent protein complement, and an additional supply of hay (From Bufano et al, 1982)

	Mixture with straw				**Mixture with olive branches**			
Vegetation water paste in the mixture %	**0**	**20**	**40**	**60**	**0**	**20**	**40**	**60**
Initial weight, kg	29.2	32.4	32.5	30.9	31.3	31.6	32.9	33.1
Final weight, kg	32.4	33.3	35.5	34.9	32.3	34.6	35.3	36.3
Duration, days	90	90	90	90	90	90	90	90
Average daily gain g/d*	35.8	10.4	34.5	45.5	11.0	33.3	26.6	34.7
Consumption								
- mixture g/d	792	992	1099	922	896	951	948	908
- hay g/d	641	602	687	700	610	664	629	676

*** The average daily gains obtained show very high variation coefficients within thedifferent lots.**

CHAPTER V: GENERAL CONCLUSIONS, PROSPECTS AND RECOMMENDATIONS

It seems clear that olive by-products represent a considerable but insufficiently exploited feed resource potential for the Mediterranean Basin. Whether these by-products be different forms of olive cake, olive leaves and branches, or vegetation waters, each one has a nutritive value which, although small, should certainly not be neglected.

Interesting research studies have been or are now being made to obtain better valorization of these by-products for animal feeding. Considerable results have been presented throughout the present study which enable the future to be viewed fairly optimistically. These by-products can and should be more and better used in animal feeding.

Considerable research and extension work must still be done to reach that objective. The following recommendations are proposed for that purpose:

A. Practical recommendations

1. **It is recommended that harvest residues and olive by-products used in animal feeding be accurately defined in order to avoid confusion and incorrect interpretation of results.**

   This terminologyproblem is often the source of the failure to understand publications when they are read. The definition given in paragraph 1.4.1 should help to provide better

knowledge of these feeds; they should be harmonized with those used in different international fora if necessary. These definitions should be supplemented with such data as the percentage of residue oil or ether extract and crude fibre in olive cake and the percentage of wood in olive branches so that these materials can be characterized better.

2. **As for their use as animal feed, detailed recommendations which could apply to all countries cannot be made. However, it is possible to recommend the general use of olive by-products (leaves and olive cake in all forms) bearing in mind that these by-products should be considered as crude ligno-cellulose feeds comparable to cereal straw or a poor quality hay.**

3. **In cases of shortage periods all types of olive cake can be recommended in survival rations, although none of them can make intensive production possible. Depending on the type of olive cake, it is possible to ensure maintenance of the animals or a moderate production level. However it is preferable to incorporate 8 to 10 percent molasses to facilitate olive cake consumption (see Table 17).**

4. **It is important that olive cake be preserved in conditions preventing their degradation by using them fresh or ensiling them (in stack silos) within three or four days after they have left the oil extraction mill when they have not been dehydrated by the oil extraction process.**

5. **It is difficult at present to recommend chemical treatment to improve the nutritive value of olive cake or leaves and branches, although the anhydrous ammonia treatment seems promising.**

6. **On the other hand, partly destoning olive cake by screening or ventilation can be**

recommended. This is the most practical, simplest and most economic method at present, and one of the most effective for improving the feed value of olive cake. Its crude fibre content should then barely exceed 15 percent of dry matter.

In regions where furfural production is planned, it is recommended that shells be separated at each refinery rather than at the furfural plant. This, while decreasing transport costs, will improve the quality of olive cake and facilitate its availability by keeping it nearer to stockraising centres.

7. **Olive tree leaves and branches constitute a fodder of exceptionally high quality (which is higher as the proportion of wood is lower). It is recommended that the leaves be used preferably fresh, since their nutritive value is higher than that of leaves which have been dried or preserved by ensilage.**

8. **Separation of the leaves from the wood whenever possible is also recommended.**

B. Recommendations for research

9. **Since experimental conditions are not always clearly defined making it often difficult and sometimes impossible to interpret results, it is recommended that an in-depth study be made based on the same initial lot of olives according to a detailed experimental protocol including various industrial processes, the phases of which will be previously described.**

   In each phase analyses and experiments are to be made to characterize and study each respective by-product (fatty or crude olive cake, partly destoned fatty olive cake, exhausted olive cake, partly destoned exhausted olive cake, pure pulp, vegetation waters).

   This type of study requires the joint efforts of research institutes, universities, managers

of the olive oil industry, and olive producers themselves. This should be possible in some countries or regions where olive production is especially important.

10. **In view of the complex character of these by-products, laboratory or on-station studies must be made, including:**

    - **specific chemical analyses including the Van Soest analysis;**
    - **digestibility studies (in vitro, in situ, in vivo);**
    - **evolution of microbial flora;**
    - **rapidity of fermentation;**
    - **degradability of crude protein and organic matter;**
    - **voluntary intake;**
    - **feeding behaviour.**

11. **It is now well recognized, especially for this type of by-products (as it is also for straw or sugarcane bagasse, for example) that the nutritive value expressed in terms of metabolizable energy or of traditional feed units, whatever they may be, has little significance. It is therefore recommended that nutritive value be expressed in terms of production performance (e.g. daily weight increases, milk production).**

12. **It is therefore necessary to increase studies on animals, by:**

    - **using the more economically important animals (sheep or goats) and preferably the**

young growing animals (lambs or kids) after weaning, or adult ewes or female goats (pregnant or nursing), but including cattle in the areas where they are more numerous.

13. **For scientific value to be acceptable, each experiment must, in particular:**

    - **include in the ration a sufficiently high proportion of the by-product to be studied (if possible as much as 60 to 80 percent of the total ration);**
    - **have a minimum duration of 90 days;**
    - **cover a sufficient number of animals (varying according to the type of control: individual or by lots respectively).**

14. **It is also recommended to increase experiments with various supplements, especially protein, energy and mineral supplements, and with a small supply of good quality fodders (berseem, lucerne, etc.)**

15. **As preliminary results are encouraging it is recommended that experiments on the use of partly destoned - by screening or ventilation - olive cake be continued.**

16. **On the other hand, experiments on chemical treatment do not seem to have priority at present due to the necessary investments, operating costs, and results in terms of improved animal production which are not always convincing.**

17. **Bearing in mind the very small number of references on the use of vegetation waters in animal feeding it is recommended that the experiments begun, especially in Italy, be continued either with vegetation waters alone or combined with olive cake to make vegetation water paste.**

18. Concerning olive leaves and branches, observation must be continued to define characterization and quantification of pruning residues according to type of olive plantation, pruning season and method, olive tree varieties, etc.

19. It is also recommended that the work recently undertaken in Spain be continued, particularly on methods of collecting, handling and separating olive branches and leaves to lower the whole cost of the process of channelling these by-products from the field to the animals, especially when the latter cannot consume them on the spot.

20. Research similar to that recommended for the study of olive cake nutritive value should be undertaken to determine the nutritive value of olive leves and branches.

21. In particular, as the influence of the preservation method on nutritive value has been shown, it is recommended that work be continued on different preservation methods (sun-drying of branches, separation and drying of leaves, ensilage, etc.)

22. Obviously olive and animal production are complementary to some extent. Since this complementarity has not been exploited to its maximum potential, it is recommended that a complete study be made on the olive plantation ecosystem, closely associating animal and olive production to the reciprocal advantage of both. The purpose will not be necessarily to maximize animal production level, but to make better use of available resources.

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