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Title: Use of Grape Pomace As A Substitute for Barley Grain In Diets of Wintering Ewe Lambs

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James E. Oldfield

Tunisia, like many other countries in the world, suffers from a shortage of feedstuffs and an overall nutrition problem is facing the livestock industry. Large quantities of feeds are imported to meet the animals' needs in energy and protein. At the same time, considerable quantities of crop residues and agro-industrial wastes suitable for use as feed for the animals are lost or underutilized. Grape pomace, which is the refuse left from the production of grape juice and wine, constitutes one of the most important crop residues, second only in volume to straw.

The purpose of this study was to assess the suitability of this by-product in dried and wet forms as supplementary feed for sheep and to determine its influence, when

incorporated in the diet at a level of 20%, on the weight gain and voluntary feed intake of sheep.

To conduct this feeding trial, 108 female lambs of an average age of 10 months including representatives of three available sheep breeds (Coopworth, Polypay and Suffolk and crosses of these), and weighing an average of about 41.5 Kg, were used over a period of 30 days. The trial was laid out in a completely randomized block design with more than one observation per block. The blocking criterion was the breed (six different breed types). Three animals from each breed were randomly selected according to their weights (heavy, medium or light) and randomly assigned to the three treatments: Control diet of barley grain, chopped grass hay and soybean meal mixed with salts and minerals; Treatment 1 of 20% wet grape pomace replacing the same amount of barley grain; and Treatment 2 of 20% dried grape pomace replacing the same amount of barley grain. Substitutions were made on a dry-matter basis

Since there were six breeds and 108 lambs in total, there were 18 lambs per group and two groups per treatment, totaling 6 groups housed in 6 adjacent pens. Daily dry matter intakes did not differ significantly among treatments. The values obtained were 1.475, 1.495, and 1.495 Kg respectively for the control, treatment 1, and treatment 2. There were, however, significant differences in daily live weight gains between treatments. The values obtained were 166, 198, and 219 g respectively for the control, treatment 1, and treatment 2.

These results indicate a satisfactory animal performance in terms of live weight gain and feed intake. Both forms of grape pomace (wet and dried) were readily accepted by sheep. These results were in agreement with the findings of other grape pomace feeding trials cited in the literature review.

Use of Grape Pomace As A Substitute for Barley Grain In Diets of Wintering Ewe Lambs

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I. INTRODUCTION

The lack of feed resources often imposes a major constraint on the development of animal production in many parts of the world, particularly during the dry or cold seasons which may last from 4 to 9 months according to the area. At the same time considerable quantities of crop residues and agro-industrial wastes, suitable for use as feed, are lost or underutilized. Ruminant animals have the ability to convert cellulose and low quality protein into human food, and in view of increasing population demand and prices of cereal grains and protein feeds, there is an urgent need to utilize agricultural by-products in ruminant feeding.

Utilizing these by-products as animal feedstuffs may also alleviate a disposal problem for some industries and become a useful, potential method in controlling environmental pollution. Many of the methods of disposal traditionally used in the past, such as burning, land spreading, burying or releasing into streams, are either prohibited or tightly restricted. The rumen, with its extensive microbial population producing cellulases and urease, makes ruminants unique in their ability to convert fibrous, low quality products and non-protein nitrogen into energy and animal protein. Consequently, energy and protein can come from sources which are not competing with human use.

Grape pomace, with a production of over 7 million metric tons per year in the world, constitutes one of the most important crop residues after straw (3 billion metric tons per year according to Jackson, 1977). Only less than 3% of this quantity of grape pomace is used as feed source for livestock (Lawrence, et al., 1983). The objectives of this study were:

- To assess the suitability of grape pomace in dried and wet forms as supplementary feed for sheep.
- To determine its influence, when incorporated in the diet at a level of 20%, on the weight and voluntary feed intake of sheep.

II. LITERATURE REVIEW

1. Definition and Production of Grape Pomace

Grape pomace is the refuse left from the production of grape juice and wine. It consists mainly of grape seeds, stems, and skins. According to Göhl (1975) grape pomace or winery pomace is about 10% by weight of the total grape input. If the grapes are stripped from the stalks before processing, the residue consists of about 40% seeds, and 60% skin and pulp. Also Göhl reported that winery waste pressed with the stalks is composed of about 30% stalks, 30% seeds and 40% skin and pulp.

The grape pomace may be separated into skin and seeds by loosening the pulp from the seeds in a breaker, after which a vibrating sieve separates the seeds from the skin. Both fractions are then dried; the marc (skin and pulp) is ground in a mill and bagged, and the dried seeds are removed from the dust and stored in silos. The seeds contain 8-22% edible oil which can be either pressed or extracted with solvents leading to another by-product called press cake.

Winery operations are seasonal; in the northern hemisphere, crushing and fermentation occurs from August to November, while distillation continues throughout the year.

In the main, grape by-products are produced in the predominant wine producing countries, including France, Italy, Germany and in particular Spain (Hall, 1981). In 1979, 2,461,324 metric tons were used for wine making in the United States. Of this amount, 96.5 percent was processed in California (U.S. Department of Agriculture, 1980). Annual U.S. production of grape pomace is about 45.4 to 72.6 million dry Kg. In Tunisia, grape pomace production was estimated to be 15,000 to 20,000 metric tons per year (Chermiti, et al., 1986).

Distilled wines are made using one of two procedures, the steam and the diffusion system (Messaoudi, 1982). These two systems will have an influence upon the characteristics of the pomace produced.

a) Steam distillation

Distillation is a very ancient procedure of alcohol extraction. From this classic system the industry has developed a new technology that involves flooding the whole grape material with steam. The steam dissolves the alcohol and is later separated from it by condensation. This system does not permit the recovery of the seeds for oil extraction.

The remaining residue is called stillage and contains 30% dry matter.

b) Distillation by diffusion

This is the most common system used in the industrialized countries. It consists of washing the grape material in a group of 6 to 10 large containers which are joined with one another by a system of pipes. The washwater is collected and distilled in order to obtain alcohol. The by-product is called "clean-up washwater" or "marc diffusion." The grape pomace remaining from this process can be conserved as a feed source for ruminant animals.

2. Preservation of Grape Pomace

The preservation of many agricultural and industrial by-products may be a problem because of their high moisture content, and this is the case with grape pomace. Some authors have reported the possibility of feeding fresh grape pomace, with the need for processing when it is available every 3 to 4 days. Adding some salt (1%) can extend this period to about 6 to 7 days if the temperature is not high (Messaoudi, 1982). For long term use, however, the pomace would need to be preserved. The two most useful methods are dehydration and ensiling.

a) Dehydration

If weather permits, the simplest form of dehydration is sun drying. The material can be spread out thinly over a hard surface and allowed to dry, with turning if necessary. If sunlight is unavailable, or unreliable, large quantities of grape pomace can be dried in rotary drum driers. Small quantities of apple or pear pomace may be combined with the grape pomace for drying. Urea may be added to the pomace as a nitrogen source. Artificial drying is one of the best methods of preservation but it requires an input of energy and therefore its cost may be high.

b) Ensiling

To avoid the cost of drying, wet grape pomace may be stored in compacted piles. Most of the mass stores safely by this method; only the outer layer deteriorates (Stokes, 1967). This is reported as an easy and economical way to preserve grape pomace, determined by several workers (Picconi, 1965; Matray, et al., 1977; Lawrence and Berthe, 1981). The loss of nutrients is kept to a minimum of about 3% because sugars present are immediately available for fermentation and the initial acidity is already high (Göhl, 1975; Messaoudi, 1982). The ensiling operation is most efficiently conducted in large silos which can be hermetically sealed. Some characteristics of the fermentation of grape pomace are summarized in Table 1 (Matray, 1977).

Table 1: Some Characteristics of the Fermentation of Grape Pomace. (Matray, 1977)

Product	pH	Dry Matter %	NH_3-N % of Total	Acetate	Propi-onate	Butyrate	Lactate
Stillage	4.1	36.66	3.89	20.89	Traces	Traces	9.54

These results are reported to reflect a good silage quality.

3. Chemical Composition of Grape Pomace

It must be emphasized that there is a considerable variation in the chemical composition of grape pomace. Variations may be due to different varieties of grapes, the fermentation process, distillation and preservation methods, area of origin, and harvesting system. Knowledge of the dry matter content and chemical composition is important for the ultimate uses of the by-product.

The main variations, according to Table 2, are among the dry matter, crude fiber, ether extracts and ash components.

Table 2: Chemical Composition of Stalks, Seeds and Pulp of Grape Pomace. (Maymone and Petrucci, 1945)

Components	D.M. %	D.M. Basis				
		Crude Protein %	Crude Fiber %	E.E. %	Ash %	NFE %
Pulp	32.66	14.56	12.36	4.93	12.96	55.19
Stalks	24.77	10.96	20.15	3.24	8.80	56.85
Seeds	58.98	10.03	47.68	7.91	3.92	30.36

Table 3: Variation in Chemical Composition of Grape Pomace According to the Origin and Composition of the Grape Pomace. (Bo Göhl, 1975)

Products/Origin	DM	As % Dry Matter						
		CP	CF	Ash	EE	NFE	Ca	P
Fresh leaves, Pakistan	30.0	15.8	9.2	8.6	13.4	53.0	2.25	0.16
Winery pomace (Stalk,skin,seed), Italy	40.6	11.7	25.5	7.7	9.9	45.2	-	-
Winery pomace (Skin,seed), Italy	46.5	13.7	23.6	12.8	7.0	42.9	0.82	0.2
Winery pomace (Skin), Italy	-	14.4	22.3	6.3	8.3	48.7	0.77	0.27
Winery pomace (Skin), Chile	88.9	18.3	32.0	8.0	6.4	35.3	1.63	0.33
Oil cake (Hydraulic press)	88.5	13.6	44.0	5.2	8.5	28.7	-	-
Seed, Chile	93.0	9.6	45.7	4.2	14.2	25.3	0.62	0.22
Winery pomace (Skin, stalk) Germany	88.0	14.9	35.8	8.9	5.0	-	-	-

The content of lignin in the grape pomace is relatively high, depending on the proportions of pulp, stalks and seeds (Table 4). Lignin is an undesirable component, since it is highly indigestible by animals.

Table 4: Percent of Lignin in Grape Pomace. (DM basis) (Maymone and Petrucci, 1965)

Grape Pomace	% Lignin	% Lignin in the Crude Fiber
Red pomace	16.69	58.93
White pomace	12.22	51.67
Dried pomace	11.47	51.38

The nutrient composition of grape pomace is influenced by the variety of grape as previously mentioned. Some indication of the extent of such variation is shown in Table 5. These two types of grape pomace differ mainly in their dry matter percentage and crude fiber content.

Table 5: Influence of the Grape Variety (Messaoudi, 1982)

Products	Components				
	% DM	% Crude Protein	% Crude Fiber	% Ether Extract	% Ash
White Reisling	23.15	12.31	23.64	5.38	9.07
Red Grape	36.28	12.32	28.32	5.78	9.70

The distillation system does not affect the chemical composition of grape pomace very much with the exception of a small variation between the stillage and cleanup washwater content of the crude fiber (Table 6).

Another factor that affects the chemical composition of the grape pomace is the procedure of conservation used. Some such variation is illustrated in Table 7. As one would expect, here the major variation is in the dry matter content in each type of pomace. Beyond this, the dried material has more fiber than the wet (ensiled) one.

Table 6: Distillation System Influence on the Chemical Composition of Grape Pomace. (% DM Basis) (Reyene and Garambois, 1977)

	% DM	% of Dry Matter			
		Crude Protein	Ether Extracts	Crude Fiber	Ash
Stillage	32.70	11.9	-	29.00	5.60
Cleanup Wash Water	32.20	13.10	8.30	24.20	6.80

Table 7: Chemical Composition of Both Ensiled and Dried Grape Pomace (DM basis)

			% of Dry Matter				
Authors	Products	DM	Ash	CP	CF	EE	NFE
Morrison (1957)	Dried	91.0	5.5	13.4	33.2	7.5	40.3
Reyne and Garambois (1977)	Ensiled	32.8	6.8	13.1	24.2	8.3	47.5

b. Comparison to other crop residues

Grape pomace is classified as a fibrous by-product. Comparison of its nutrient composition to that of the cereal straws shows that grape pomace is about 4 times richer in crude protein, 8 times richer in fat, but approximately equivalent in its content of ash (Table 8).

Many authors (Jackson, 1977; Sauvant, 1978, Hammouda and Lawrence, 1981) reported that grape pomace has 4 times less cellulose than cereal straws such as barley, wheat and oats but has 4 times more lignin than those straws.

Table 8: Chemical Composition of Grape Pomace and Cereal Straws (Hammouda, et al., 1981)

Residues	DM	Components in % of DM			
		CP	CF	Fat	Ash
Grape pomace	43	14	31	8	6
Barley straw	88	3	42	1	7
Wheat straw	88	3	42	1	6

4. Mineral Composition of Grape Pomace

As shown in Table 9, both grape pulp pellets and grape seed meal appear to be potentially good sources of calcium but are poor sources of phosphorous, magnesium and sodium. Possibly because of the use of copper fungicides, there may be a high and potentially toxic level of copper in grape pulp pellets (Morgan and Trinder, 1980) however Hall (1981) reported that from the evidence available neither the grape seed nor pulp has been shown to possess any toxic properties although some samples do contain small quantities of theobromine and caffeine.

5. Amino Acid Composition of Grape Pomace

Although the total nitrogen content, as reflected by crude protein level is of most use in feeding ruminant animals, data on protein quality in terms of amino acid content may be of interest. Table 10 gives the amino acid composition of two different grape pomace products: Ensiled whole grape pomace, made in Tunisia and dried grape pomace made in Spain (Sanchez, et al. 1977, Chermiti, et al. 1986).

Both results showed that glutamic and aspartic acids constitute the most plentiful amino acids in the grape pomace as compared to the rest of the amino acids in the list.

Table 9: Essential Minerals in Grape By-products (Morgan and Trinder, 1980)

Minerals	Products	
	Grape Pulp Pellets	Grape Seed Meal
Calcium (%)	0.76	0.78
Phosphorous (%)	0.17	0.17
Magnesium (%)	0.07	0.07
Sodium (%)	0.09	0.04
Copper (mg/Kg)	142	29
Zinc (mg/Kg)	20	-
Manganese (mg/Kg)	18	24
Cobalt (mg/Kg)	0.45	0.12
Selenium (mg/Kg)	0.11	0.04

-: unavailable data

Table 10: Amino Acid Composition of Grape Pomace.

Amino Acid	Crude Protein Basis (%)	Dry Matter Basis (mg/100 g DM)
Aspartic Acid	8.13	664
Glutamic Acid	18.02	1472
Threonine	3.37	420
Serine	3.98	475
Proline	5.85	202
Leucine	6.04	647
Phenylalinine	3.76	590
Lysine	5.04	602
Arginine	4.98	650
Glycine	5.63	600
Valine	5.16	452
Methionine	1.27	126
Isoleucine	3.68	555
Grape pomace	Ensiled Pomace (Tunisia)	Dried Pomace (Spain)
References:	Chermiti, et al. 1986	Sanchez, et al. 1977

6. Digestibility of Grape Pomace

Besides the implications of the chemical composition of grape pomace for its use as animal feed, some authors mention a large variation in digestibility within pomace samples. For example the organic matter digestibility of grape pomace has been reported to range between 14 to 28% (Reyne and Garambois, 1983). This fluctuation of dry matter digestibility is due to many factors. Some of these factors are discussed later, with their effects on the digestibility of grape pomace.

a) Variety of grape pomace and animal species

A recent study conducted by Famuyiwa and Ough in 1981 in California showed that the digestibility of several pomace varieties determined in vitro by using rumen fluid from different animals (cow, sheep, goat) had low values (26-39%) when compared to those of alfalfa hay (69%) or sudan grass (65%). The results of this study are summarized in Table 11.

From these figures (Table 11) Cabernet Sauvignon pomace had the highest digestibility, 38.6% in cows, while Tinta Madeira pomace consistently had the lowest digestibility, 25.9% in both cows and sheep. These values are much lower than the 63.7% to 78% obtained for the two hays. However, barley straw, which is a routine part of rations for dry cows

Table 11: Dry Matter Digestibility of Pomace Varieties in Different Animals (Famuyiwa and Ough, 1981)

	Dry Matter Digestibility, %		
Pomace Variety	Cow	Goat	Sheep
Cabernet Sauvignon	38.6	35.1	36.6
Gerwurtztraminer	35.9	31.4	34.4
Tinta madeira	25.9	26.9	25.9
Alfalfa hay	68.6	66.9	70.2
Sudan grass hay	64.6	78.0	63.7

was found to have an in vivo digestibility of 37.9% in sheep when fed with fat, urea phosphate and sulphur salts (Nelson, 1979, and Oh, et al., 1971).

Difference in digestibilities among the varieties is to be expected due to a difference in chemical composition and to different fermentation treatments. The lowest digestibilities generally corresponded to the highest level of phenol content, as suggested by the same study. The authors reported also that a 4% tannin level in the pomace decreased the digestibility of grape pomace slightly, and there is no negative interaction when the pomace is mixed with the hay in equal quantities. It was suggested that use of seedless grapes may contribute to increased digestibility of the pomace.

b) Effect of preservation method on digestibility of grape pomace

The results of two studies conducted in France using both dried and ensiled grape pomace are summarized in Table 12 (Reyne and Garambois, 1977; Dumont and Tisserant, 1978). These studies confirmed the one cited earlier in reporting a low digestibility of grape pomace. In particular, the protein in both dried and ensiled pomace has a very low digestibility (13%). However the digestibility of organic matter of the dry material appears to be much higher than that of the ensiled pomace (28% compared to 40%).

The low digestibility in both cases (Tables 11, 12) has been attributed to the high content of tannin in both materials which plays an important role in determining the protein solubility.

c) Effect of feeding level

Many authors have found that organic matter digestibility was affected by the feeding level used. Digestibility with ad libitum feeding was lower than at maintenance level. Folger (1940) found that grape pomace is poorly digested when incorporated at high levels (>50%) in the ration. The values

Table 12: Digestibility of Dried and Ensiled Grape Pomace (%)

		Digestibility, %			
Authors	Product	Organic Matter	Crude Fiber	Crude Protein	Ether Extract
Reyne and Garambois (1977)	Ensiled	25-28	16-26	8-13	48
Dumant and Tisserant (1978)	Dehydrated	46	10	13	91

for total digestible nutrient (TDN) ranged from 24 to 30 percent, air-dry basis.

Economides and Georghiades suggested in 1980 that grape pomace could be successfully included at between 10 and 15% in rations for lamb fattening. Prokop (1979) fed grape pomace at 20% of the diet to beef cattle on a finishing diet without any negative interaction with digestibility.

d) Effect of supplementary protein source on the digestibility of grape pomace

In a study conducted by Lawrence and Yahiaoui in 1981, protein supplementation of grape pomace increased the digestibility of the total organic matter of the mixed ration from an average of 31% to 46%.

Digestibility of the diets appeared closely related to the amount of fermentable nitrogen supplied by the protein source. The digestibility reached 40% and 50% respectively when urea and repressed soybean oil meal were used as supplements.

e) Effect of chemical treatment on grape pomace digestibility

Lawrence, Hammouda and Gaouas (1983), found that sodium hydroxide treatment increased digestibility from 32% (non-treated pomace) to 44% (pomace treated with 0.67% NaOH). Treatment with 1.11% NaOH led to a slight decrease in the organic matter digestibility (41%). The improvement of digestibility involved all the pomace components and most particularly cellulose and lipids (25% and 61% respectively). Nitrogen digestibility remained low on an average (20%) but varied from 10% (non-treated pomace) to 29% (pomace treated with 0.67% NaOH).

f) Nutritional value of grape pomace

The large variation in chemical composition coupled with a wide range of digestibility coefficients must result in extensive fluctuations of feeding value of various types of grape pomace.

Only a few studies on its feeding value have been conducted, but grape pomace has been fed to ruminant animals in the United States and in some Mediterranean countries (Spain, Greece) for many years.

Huber (1983) stated that when grape pomace is used as the whole diet it has very little feeding value, being very low in both energy and protein. When included in a concentrate mix, it can be considered only as a filler to reduce the price of the mix. However, the waste without stems has been fed successfuly at 15 to 20% level in complete feedlot rations.

The same author reported the following energetic values for dried grape pomace when included in dairy cattle rations: Dry matter 91%, Total Digestible Nutrients 30%, and energy fractions expressed as Mcal/Kg DM of NE_m 0.74, NE_g 0, NE_l 0.61, where NE_m is the net energy for maintenance, NEg is the net energy for gain and NE_l is the net energy for lactation. In a study conducted by Prokop (1979) in California, grape pomace was fed at 20% of the diet to beef cattle (finishing steers), net energy values were: NE_m 0.75 Mcal/Kg, and NE_g 0.41 Mcal/Kg on dry matter basis.

Another study in Cyprus by Hadjipnayioutou and Louca in 1976 showed that the ME of dried grape pomace was 1450 Kcal/Kg dry matter basis, approximately half that of barley. The grape pomace was fed as 15 and 30% of calf fattening diets with urea added to compensate for the expected low digestibility of grape pomace protein.

In another experiment conducted in Cyprus in 1974, Economides and Hadjidemetriou used dried grape pomace at a level of 20% of a mixed ration for sheep containing chopped straw, crushed barley, soybean meal and dicalcium phosphate. The results of this experiment showed a digestibility coefficient of 28.5% for the dry matter, 29.7% for the organic matter and 19.5% for the protein. The authors reported also a digestible protein of 2.3%, an ME of about 1030 Mcal/Kg, a TDN of 26.4% and a starch equivalent of 25.2%. These results confirm the low energy and digestible protein content in the grape pomace, and because of these deficiencies, the authors suggested that grape pomace is suitable for fattening animals on ad libitum feeding.

g) Grape pomace use and animal performance

Grape pomace has been used as a feed source for animals at different levels of incorporation in their diets, in different forms (dried pellets, wet material), with or without protein supplementation (urea, alfalfa, repressed oil meal) and in treated or non-treated form (with NaOH or intact). All these feeding trials reported results relevant to the animal performance in terms of live weight gain or loss, feed intake and feed conversion efficiency. Some of these results are presented here (Table 13).

The intake of grape pomace depends on the type of pomace, form and quality of preservation and the energetic and protein supplementation. The intake of ensiled pomace is high and variable when it is fed to sheep. The ensiled waterwashed grape marc (diffusion) is consumed in lower quantities than the ensiled steam washed grape marc (stillage).

Table 13: Intake Level of Grape Pomace as a Complete Ration for Sheep

Pomace Type	Kg DM/100Kg of live weight	References
Ensiled Stillage	3.7	Reyne and Garambois (1977)
Pomace Diffusion	1.5	Reyne and Garambois (1977)
Dried Pomace Pellets (5mm diameter)	0.5	Dumant and Tisserand (1979)

The amounts of dried pomace consumed are far less, probably because of low palatability related to its physical form (pellets) and the absence of sufficient protein.

Reyne and Garambois also reported that grape pomace intake increased when a protein supplement was used. Sanchez, et al., (1977) obtained an average daily weight gain of about 150 gr. when they fed dried grape pomace ad libitum supplied with 1 Kg of alfalfa to lambs (local breed) for a period of 61 days. This gain in lamb live weight was considered satisfactory for the breed used. The results of this study are summarized in Table 14.

Dried grape pomace has been used in feeding trials conducted in Cyprus as a substitute for barley grain in diets of fattening lambs, calves, and dairy cows.

In 1980, Economides and Georghiades carried out two trials, one with 50 and other with 58 Chios lambs over periods of 84 and 56 days respectively, to study the effect of grape pomace as a substitute for part of the barley grain in lamb fattening diets. In both trials two diets containing either zero or 30% grape pomace were used.

Male lambs grew similarly on the two diets in both trials. Female lambs fed the grape pomace diet gained sightly more live weight in both trials than female lambs on the control diet. This was the result of higher (11%) energy intake by females fed the grape pomace, presumably because it

Table 14: Weight Gains of Lambs Fed Grape Pomace and Lucerne. (Sanchez, 1977)

Lamb #	Daily Weight Gain (g/day)	Intake Kg/day
1	99	1.857
2	130	1.787
3	170	1.835
4	175	1.840
5	201	1.859
6	142	1.797
7	135	1.826

was more palatable and also had a lower energy content. All lambs on the grape pomace diet consumed more feed, but their conversion of it was poorer. The results of both trials are given in Table 15.

Table 15: The Effect of Grape Pomace on the Growth of Lambs in Cyprus Feeding Experiments. (Economides and Georghiades, 1980)

	Trial 1				Trial 2			
Level of Pomace Fed	0%		30%		0%		30%	
	Male	Female	Male	Female	Male	Female	Male	Female
Number of Lambs	10	10	10	10	14	14	14	14
Initial Weight (Kg)	26.6	21.9	26.6	22.7	20.3	18.0	20.3	18.2
Final Weight (Kg)	51.8	38.6	51.7	40.9	35.5	30.0	36.2	31.4
Days on Trial	89	89	89	89	56	56	56	56
Weight Gain (Kg)	25.2	16.7	25.1	18.8	15.2	12.0	15.9	13.2
Feed Intake (Kg/day)	1.42	1.19	1.73	1.56	1.12	0.94	1.46	1.30
Feed/Gain	5.01	6.33	6.13	7.35	4.12	4.39	5.14	9.53
ME Intake (MJ/day)	15.9	13.3	16.1	14.5	12.7	10.7	13.9	12.4

The results showed a similar response to grape pomace diets in live weight gain of lambs in the two trials, though the age of lambs was different. The authors questioned whether drying and grinding the grape residues is worthwhile considering its nutritive value in relation to the present prices of barley grain. They also suggested the possibility of ensiling fresh grape pomace with urea to avoid drying costs.

In another study by Mavrogenis, et al. (1973), 80 Chios lambs weaned at 45 days of age were randomized into four groups. One group was fed a pelleted concentrate ration on barley, while the remaining three groups were fed rations containing 40% of either grape pulp, grape seed meal or molasses-treated grape seed meal.

Daily live weight gains did not differ significantly among treatments, however there were significant differences in feed conversion efficiency. The values obtained were 5.4, 6.8, 7.5 and 7.4 Kg of feed per Kg live weight gain for the concentrate, grape pulp, grape seed meal and molasses-treated grape seed meal rations respectively. The complete results of this feeding trial are shown in Table 16

According to the figures in Table 16, the inclusion of the various grape waste roughage sources in the rations caused substantial increases in feed intakes due presumably to the ruminants' tendency to eat to achieve a constant energy intake. The intake increases in diets B, C, and D containing the dried grape residues were 21, 25, and 30% respectively over that on the concentrate diet.

The growth performance was somewhat low, reflecting both the lower energy content of the rations and the relatively low potential growth rate of Chios lambs.

Table 16: Mean Live Weight Gains, Feed Intakes and Feed Conversion Efficiency of Lambs Fed on Four Different Pelleted Diets. (Mavrogenis, et al., 1973)

	Concentrate (A)	Grape Pulp (B)	Grape Seed Meal (C)	Molasses Grape Seed (D)	SE
Initial Weight (Kg)	15.5	15.7	15.4	15.3	0.342
Final Weight (Kg)	37.2	36.8	36.7	36.8	1.070
Days on Trial	101	103	112	107	6.191
Weight Gain (Kg)	0.223	0.216	0.197	0.207	0.011
Feed Intake (Kg/day)	1.140	1.380	1.420	1.480	
Feed Conversion (Kg/Kg gain)	5.35	6.51	7.53	7.43	

Dried grape pomace has been also fed to growing calves. Hadjimetriou and Louca from Cyprus reported in 1976 that the inclusion of grape pomace at 15 and 30% of calf-fattening diets based on barley, tended to reduce live weight gains at the higher level and reducing killing out percentage and to increase feed intake at both levels, resulting in poor feed utilization. Its value as an energy source appears to be about half that of barley. The calves were on this trial over a period of 30 weeks. The results are presented in Table 17.

Table 17: The Effect of Grape Pomace on the Performance of Friesian Male Calves. (Hadjipanayioutou and Louca, 1976)

	0% Grape Pomace	15% Grape Pomace	30% Grape Pomace
Number of Calves	10	10	7
Initial Wt. (Kg)	153.5	156.9	148.0
Final Wt. (Kg)	412.1	416.6	390.0
Days on Trial	210	210	210
Weight Gain (Kg/day)	1.23	1.24	1.15
Feed Intake (Kg/day)	57.40	56.9	56.5

In Tunisia, Chermeti, et al. (1986), fed ensiled whole grape pomace (including stalks) as either a complete ration or in a mixed ration for sheep (4-year-old rams) and reported an increase in the quantities consumed when energy or protein supplementation was added. The intake increases more when 400 g of concentrate based on barley was added. The animals did not lose weight. The feed intake results are given in Table 18.

Table 18: Intake of Ensiled Grape Pomace in Three Different Rations. (Chermeti, et al., 1986)

Intake	Ensiled Grape Pomace As Complete Ration	+ 400 g Concentrate + Urea	+ 400 g Concentrate + Field Beans
g/day	1594±15	2014±328	1971±199

The results in Table 18 showed that supplementation of 400 g of barley-based concentrate increased the total intake by about 20% in both mixed diets compared to the ensiled grape pomace fed as a complete ration.

In another study conducted by Lawrence and Yahiaoui in Algeria in 1981 concerning the effect of different protein sources on the nutritive value of grape residues, results showed that when sheep were fed ensiled grape pomace as a complete ration, they lost weight (-130 g/day) even though the intake was high (89 g/Kg wt .075). When grape pomace was supplemented by different protein sources the intake increased and reached an average of about 1700 g/day. The animals weight gains were 71 g, 109 g, 137 g and 13g per day on rations supplemented with field beans, soybean meal, dehydrated alfalfa and urea respectively.

These authors also reported that according to the results of this feeding trial, the nutritive value of grape pomace was superior to that of straw with the same quantity of concentrate. Grape pomace is apparently most useful for animals at maintenance or a moderate growth rate. Another advantage mentioned by the same authors which gives credit to grape pomace is that it does not require a high cost for harvesting, or a large place for preservation and storage, and it is easily ensiled.

Göhl (1975) reported that winery pomace from grapes with stalks on, has been fed to dairy cows in amounts up to 6.5 Kg per day. When supplemented with concentrates and legume hay, it proved to be a good feed. At this level of incorporation, the milk yield tends to drop but the butterfat content increases. Grape pomace without stalks has a low fiber content and has been used for horses in proportions of up to 10% of the ration (Göhl, 1975).

Owing to its high fiber, low energy and low amino acid levels, it is unlikely that grape pomace will find a place in monogastric diets, other than perhaps as a low-cost filler.

The available literature leads one to the conclusion that grape pomace is an important feed source for ruminants, even though its chemical composition, digestibility and feeding value can fluctuate for various reasons. Ensiling wet grape pomace seems to be a good preservation method, resulting in a product that is attractive to ruminant animals and economical in terms of costs of processing.

In summary, grape pomace is a low quality fibrous product and animal performances decrease when the amount of it in the diet is increased. This residual material is more suitable for animals with lower nutrient requirements (maintenance, rather than growth).

More research on the efficient utilization of grape pomace in livestock husbandry is necessary. With this in mind, the results of a feeding trial using grape pomace in two forms (wet and dried) and at a low level of inclusion (20%) in a mixed ration based on barley for sheep will be presented and discussed in the third part of this study.

III. EXPERIMENTAL

Tunisia and many other countries in the world suffer from a shortage of feedstuffs, and large quantities of feeds are imported annually from the United States and other Western countries to meet the needs of the livestock industry. Regarding the increase of cereal grains and protein prices, there is an increasing need to utilize agricultural by-products in ruminant feeding.

Grape pomace is a by-product of the wine industry and it is a physical mixture of grape skin, grape pulp and grape seeds. This by-product is available in large quantities in wine producing countries such as Tunisia, but most of the time it is under-utilized or wasted. Earlier studies show that grape pomace can be used as a feed source for ruminants and that its nutritive value would appear to depend to some extent on its chemical composition and its physical form (wet or dried). Further studies are needed to investigate the influence of the level of its inclusion in the ruminant ration.

The purpose of this study was to estimate the effects of replacing barley grain with grape pomace (wet and dried forms) at a level of inclusion of 20% for ewe lamb wintering diets.

The measurement used was the live weight gain and feed intake of three available breeds of sheep and their crosses.

1. Materials and Methods

a) Animals

One hundred eight (108) female lambs averaging 10 months of age and including representatives of three available sheep breeds were used in this feeding trial. The breeds used were Coopworth, Polypay and Suffolk and crosses of these and weighing an average of about 91.4 lb or 41.5 Kg. The lambs were housed in the Sheep Barn at Oregon State University and group fed in open, lean-to sheds. An ad libitum supply of water was available. Live weights were obtained at the start of the trial and at weekly intervals thereafter for a period of thirty days.

The animals are owned by the Animal Science Department at Oregon State University and were brought from ryegrass pasture to the experimental barn feeding site. They were put on the treatment diets for two weeks as a pre-experimental orientation period.

b) Feeds

Supplement: Grape Pomace. The fresh wet grape pomace was provided gratis by Alpine Vineyards southwest of

Corvallis, Oregon. The wines made in this winery include Chardonney, Pinot Noir, White Riesling, Gewurztraminer, Cabernet Sauvignon and Blanc des Blancs (a dry blend of whites). The grape pomace provided was from two varieties: Cabernet Sauvignon and Pinot Noir for red pomace and White Riesling for white pomace. The grape pomace was composed of seeds, skin and pulp with no stalks included. Some of the grape pomace was spread on a clean concrete slab for a few days for drying, but because of local rainy weather, it was impossible to continue with this simple procedure to decrease the moisture content of the material. Alternatively, it was removed inside to a concrete-flooring storage building where an electric heater and fan were used to dry enough material for the ensuing trial.

The rest of the pomace was placed, fresh, in plastic bags, with most air excluded and allowed to ferment (a quantity of 50 lbs in each bag) for about two weeks.

Due to unexpected amounts consumed by the sheep, in the last week of the trial, a shortage developed in the supply of ensiled pomace and no more was available from Alpine Vineyards, therefore an additional quantity of wet material was brought from Hidden Springs Winery, west of Salem. This was from the same variety (White Riesling) as the first pomace obtained.

Basal Ration. This was composed of whole barley grain, chopped grass hay and a mixture of soybean meal, minerals and salts. These feedstuffs were provided by the Experimental Feed Mill at Oregon State University. The composition and analysis of the feeds used in this trial are given in Tables 19 and 20. The chemical analyses were conducted in the nutrition laboratory in the Animal Science Department. The grape pomace was incorporated in the diets as a replacement for 20% of the barley grain.

Table 19: Composition (%) of the Diets (Dry Matter Basis)

Feeds %	Treatments		
	Control	Treatment 1	Treatment 2
Whole Barley Grain	70	50	50
Grass Straw	18	18	18
Soybean + Minerals + Salts	12	12	12
Dried Grape Pomace	0	0	20
Wet Grape Pomace	0	20	0

Table 20: Analysis of the Feeds in the Diets (Dry Matter and As Is Basis)

Identification	Crude Protein	Acid Detergent Fiber	Ether Extract	Ash	Basis
Grape Silage (White)(1)	11.29	47.77	5.54	9.51	DM
(% DM = 25.59)	2.89	12.22	1.52	2.43	As Is
Dried Pomace (Red)	8.86	36.79	5.21	6.16	DM
(% DM = 79.40)	7.03	29.21	4.14	4.89	As Is
Chopped Hay	8.66	37.29	1.66	8.18	DM
(% DM = 87.06)	7.54	32.46	1.45	7.12	As Is
Whole Barley	11.17	16.39	2.09	4.62	DM
(% DM = 89.56)	10.00	14.68	1.87	4.14	As Is
Soy Bean Meal + Minerals	38.40	8.22	0.48	28.66	DM
(% DM = 89.92)	34.53	7.39	0.43	25.77	As Is
Wet Grape Pomace (White Reisling)(2)	14.18	55.99	9.79	7.04	DM
(% DM = 24.72)	3.32	15.52	2.71	1.95	As Is

(1) From Alpine Vineyards
(2) From Hidden Springs Winery

c) Experimental design

The trial was laid out in a completely randomized block design with more than one observation per block. The blocking criterion was the breed (six different breeds). Three animals from each breed were randomly selected according to their weights: Heavy, medium or light, and randomly assigned to the three (3) treatments (control, ensiled grape pomace, or dried grape pomace). Since there were 6 breeds and 108 lambs in total, there were 18 lambs per group and two groups per treatment, totaling 6 groups housed in 6 adjacent pens. For each treatment, one of the 2 groups was composed of animals which had been the subject of a previous experimental treatment (early exposure to Tansy ragwort, Senecio Jacobea), the other had animals which were not previously treated.

Figure 1 illustrates the experimental design.

d) Procedures and measurements

The experimental diets were hand fed separately to the animals. The hay was given first, barley second and the mixture (soybean meal + minerals + salts) third for the control groups. For the other groups, grape pomace was added last. Each feed was weighed before being distributed, and the amount given was as planned to supply the desired percentage of each feed in the diet (Table 19) Animals were fed a total amount of feed which exceeded the requirements for dry matter

Figure 1: Graphic Representation of Experimental Treatments.

*Rep 1	Rep 2	Rep 1	Rep 2	Rep 1	Rep 2
18**	18	18	18	18	18
Control		Treatment 1		Treatment 2	

*Rep = Replication
**18 animals per group

Table 21: Table of Analysis of Variance

	Source of Variation	Degrees of Freedom
1)	Breed (Block)	6 - 1 = 5
2)	Repetition (Rep)	2 - 1 = 1
3)	Breed X Rep	5 X 1 = 5
4)	Treatment (Trt)	3 - 1 = 2
5)	Breed X Trt	2 X 5 = 10
6)	Rep X Trt	1 X 2 = 2
7)	Breed X Trt X Rep	5 X 1 X 2 = 10
8)	Error	72
	Total	108 - 1 = 107

recommended by NRC (1975) for replacement lambs of 40 Kg body weight. This requirement is 1.4 Kg of dry matter per day, per animal.

Group feed intakes were measured every other day. Individual live weight changes were measured weekly.

2. Results

a) Live weight gain

The ANOVA does not show any significant interaction between breed and treatment as well as any significant difference in the daily weight gain values between breeds (see Table 22). Also, under the same treatment, values of daily weight gain were not significantly different between previously treated group individuals and those under no previous treatment. The only significant difference was shown among the different treatments. The values for the average daily weight gain (g) for each treatment are given in Table 22. The difference between these means was highly significant (p value = 0.0073).

Table 22: Daily Weight Gain (g) for Each Breed Under Each Treatment.

	Breed*						Overall Mean
	1	2	3	4	5	6	
Control	179	181	133	161	148	194	166
Treatment 1	186	201	161	179	209	252	198
Treatment 2	234	191	179	239	247	227	219

*Breed Genotypes
Coopworth = C
Polypay = P
Suffolk = S

Breed 1 : CC 2 : PC 3 : CP
4 : SP 5 : PP 6 : SC

b) Feed intake

There was no significant difference either between treatments or between replications within treatment (p value = 0.309) in daily dry matter intake (group feeding).

Values in Table 23 show that the same amount of feed was consumed by animals in either treatment 1 or treatment 2 and is slightly higher than the amount consumed in the control group. Both forms of grape pomace were readily accepted by

Table 23: Average Daily Dry Matter Intake for Each Treatment (Kg).

Control	Treatment 1	Treatment 2
1.475	1.495	1.495

the sheep, and apparently were satisfactory substitutes for more conventional ration ingredients, in terms of palatability.

3. Discussion

a) Chemical composition

The results of the chemical analysis of the grape pomace in both forms (wet and dried) agreed with previous analyses in showing a low crude protein content, a high crude fiber and fat content of the dry matter of the grape waste. Slight differences in the percentage are apparently due to the varieties used, processing techniques and countries of origin.

The values obtained for the crude fiber of the grape pomace used in this study (47.77% and 36.79% of the dry matter respectively for wet and dried material) were higher than those reported by Sanchez (1977), 26.33%, Economides and

Georghides (1980), 35.4% and Chermiti, et al. (1986), 34.1%. Reyne and Garabois in 1977 used different ensiled grape pomaces containing 29%, 24.6% and 24.2% of crude fiber. In the same country, France, Dumont and Tisserand (1978) used a dried grape pomace containing only 12%. The difference among these crude fiber contents is presumably due to the systems of ensiling and drying grape pomace. Much more complex production technology was used in those studies than in this work.

Crude protein and fat contents were in similar ranges (10-12% and 5-10% of dry matter respectively) to those in the previously mentioned references.

The digestibility of the dry matter components was not determined in this study but it is expected to be low especially for the protein. The digestible protein content in the dry matter was 2.3% (Economides and Hadjidemetriou, 1974) and the metabolizable energy (ME) content was 1.45 Mcal per Kg dry matter (Sanchez and Norberto, 1971; Economides and Hadjidemetriou, 1974). For comparison, the metabolizable energy content of barley is 3.1 Mcal/Kg dry matter and its digestible protein is 8% (National Research Council, 1975); thus grape pomace contains about 50% of the metabolizable energy and 29% of the digestible protein of barley grain. According to these results on the chemical composition and digestibility of the dry matter components of the grape pomace, the latter product cannot be used as a complete ration and should be supplemented by a protein source to compensate for the digestible protein deficit. One possible available protein source is soybean meal which contains about 40% crude protein.

b) Animal performance

The response in terms of live weight gain to grape pomace either dry or wet was higher compared to the performance on the control diet. This is in agreement with the finding of Economides and Georghiades (1980) with dried grape pomace at a 15% level of inclusion in a barley-based diet. The values of 166, 198 and 219 g of daily weight gain reported in the present study are considered to be normal for the sex and age of the animals used in the experiment (female and 10 months respectively) (NRC, 1975).

With younger females (2-3 months of age) and using dried grape pomace at 40% of a barley-based diet, Mavrogenis, et al. (1973) reported an average daily weight gain of 216 g, which was considered not different from the weight gain of animals on the control diet (223 g). Sanchez (1977) fed a mixture of dried grape pomace and fresh alfalfa to young lambs and obtained average weight gains ranging from 99 to 201 g per day. This weight gain was expected and the mixture accordingly was considered as "a perfect nutritional combination."

The intakes in this study were high and ranged from 1.792 Kg and 1.859 daily.

All these authors mentioned that the inclusion of a roughage source such as grape pomace resulted in substantial increase in feed intake, over a more highly concentrated diet, due presumably to the ruminants' tendency to eat to a constant energy intake. This increase ranged from 15 to 20% and can be explained by the low energetic value of grape pomace. Despite the apparent low metabolizable energy (ME) values of this feed, it can be used to advantage by animals with low requirements, such as wintering ewes and lambs which are merely maintaining their weight.

The results of our study showed a slight increase in dry matter intake for diets including grape pomace, but when statistically compared to the control diet this is not significant. The quantities consumed in our feeding trial were less than for other studies mentioned above. They ranged between 1.475 Kg for the control treatment and 1.495 Kg for grape pomace treatments. The difference is due to the type of animals used, method of feeding, the ingredients in the diets used and the level of inclusion of grape pomace in the ration (20% compared to 30 to 40% in other studies). This may also be due to less wastage, since the feeding was well controlled.

The energy level of the diets used in our study is expected to be higher than those used in previous experiments.

This can explain in part the live weight gains obtained from this feeding trial which does not necessarily reflect an increase in the dry matter intakes.

c) Economic feasibility

The economic feasibility of using grape promace in ruminant feed depends of course on price relationships with existing costs of other sources of energy and in particular barley. The value of grape pomace was calculated on the basis of its nutritional worth, for example, its metabolizable energy and digestible protein content, since energy and protein make up 90% or more of the cost of nutrients (Summers and Leeson, 1978). According to Economides and Georghiades (1980) one metric ton of dried grape pomace is worth 11.5 Pound Sterling when ground barley grain and soybean meal are sold for 35.4 per ton and 130 Pound Sterling per ton, respectively.

Using these figures as a basis, in the USA, one ton of grape pomace would be worth $50 when rolled barley and soybean meal are selling for $120 and $300 per ton respectively, thus grape pomace is worth considerably less than barley grain. At the level used in this study, sheep performance suggested that the grape pomace might be evaluated somewhat higher, however costs for transportation and processing would tend to offset this advantage.

Since a unit of protein supplement costs considerably more than a unit of energy, the use of urea instead of soybean meal as a nitrogen supplement in ruminant diets containing grape pomace could narrow the difference between the price of grape pomace and that of barley grain, when the price for urea is favorable.

Many research workers (Mavrogenis, et al., 1973; Economides and Georghides, 1980; Dumont and Tisserand, 1978) reported that it is doubtful if drying and grinding the dried grape pomace is worth while considering its nutritive value in relation to the present prices of barley grain.

This explains in part why grape pomace was used in our study in two simple forms (ensiled and naturally dried) without further processing, to reduce the costs of these materials.

IV. CONCLUSIONS

The incorporation of grape pomace into rations for sheep at a level of 20% has supported satisfactory animal performance in terms of weight gain and feed intake, even though grape pomace appeared to be too low a quality feed for use as a complete diet. The results of this study suggested also that the best use of grape pomace could be in a mixed ration in which a nitrogen supplement (soybean meal or urea) could be added to compensate for the low digestibility of grape pomace protein.

Both forms of grape waste are readily accepted by sheep presumably because they are quite palatable, however in order to decrease the drying and grinding costs, grape pomace could be used in a wet or partially dried form. There are a number of questions which must be evaluated before such processing methods are used for preserving grape pomace:

1) What is the potential variation in dry matter and nutrient content?

2) Will there be any moisture losses during storage?

3) Is specialized handling, storage or feeding equipment required?

4) Are there potential fly and odor problems when dealing with large quantities?

5) How can the material be stored, and what are the expected storage losses?

6) How long can the material be stored and still remain fresh?

7) Is there any physical or chemical treatment of grape pomace to increase its nutrient digestibilities?

Thus, a cooperative effort between producers and research workers, extension agents and the feed industry is required to effectively and safely use the grape pomace or any other by-product feed. This point is of great importance especially in Tunisia, where an overall nutrition problem is facing the livestock industry. The lands are overgrazed and have very low forage productivity. This overgrazing problem has been caused by mismanagement of the lands and severe climatic conditions. A need exists for other sources of feed to maintain livestock productivity, especially during winter. Grape pomace exists in large quantities and involves a large area of the country. This agricultural by-product is available at a low cost compared with other feedstuffs such as alfalfa hay and barley grain.

Therefore, there is a need for effective economic use of this and other by-products because no organized scheme of processing and use currently exists. For example, the grape pomace is not presently used for any purpose and it is generally burned and wasted.

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