Investigation into the Use of Citrus
By-Products as Animal Feeds in Greece

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INTRODUCTION

Countries around the Mediterranean basin yield one quarter of world production of citrus fruits (Bampidis and Robinson 2006), Greece together with Spain and Italy being the major producers. A part of the citrus fruit yield, predominantly oranges, is industrially processed for juice production. The by-product, namely citrus pulp, is used in various forms as feed supply for animals (Gohl 1981). Sheep keeping is the dominant animal production activity in the area (Zygogiannis 2006; Volanis et al. 2007). Therefore, the utilisation of citrus industry by-products as animal feeds for this sector needs further research (Volanis and Zoiopoulos 2003), so that attempts have been made over the years in Greece to study the nutritive value of citrus by-products for ruminant animals, particularly sheep.

The present paper quotes and commends on all works done in Greece in the field of utilisation of citrus by-products carried out with ruminant animals, including lactating ewes, fattening lambs or dairy cows. In addition, digestibility studies are reported using wethers (castrated male sheep). Furthermore, various methods of preservation of fresh citrus pulp are suggested i.e. dehydration, ensiling, whereas the issue of biotechnological upgrading of citrus by-products is also touched upon. Finally, results obtained in Greece are briefly discussed in relation to international literature.
DRIED CITRUS PULP

To increase the usefulness of citrus pulp it can be preserved by drying. The first step in drying is the addition of a small amount of lime to the fresh pulp in order to neutralise the free acids and destroy the hydrophilic nature of the pectin. Various efforts have been made in Greece to study the nutritive value of dried citrus pulp with different species and physiological stages of ruminal animals. In addition digestibility studies have been carried out to assess the digestibility of dried citrus pulp through balance trials using wethers.

Lactating ewes

In an experiment carried out by Fegeros et al. (1995), 26 lactating ewes of the local Karagouniko breed were used to study the nutrient utilisation of Dried Citrus Pulp (DCP) for milk yield when DCP was used as a replacement for cereal grains. The ewes were divided into two groups immediately post-weaning and fed daily 700 g of alfalfa hay, 300 g of wheat straw and 580 or 550 g of concentrates with or without 30% of DCP respectively. The inclusion of citrus pulp in the diets of ewes had no significant effect on milk yield and composition but decreased the C14 to C10 fatty acids in milk. The same authors concluded that DCP is a valuable, high energy by-product that can partly replace cereal grains in sheep rations without adverse effect on milk yield or composition.

Fattening lambs

Koutsotolis and Nikolaou (1995) studied the effects of replacing maize grain with DCP in various proportions of the diets using local Epirus mountainous breed of sheep on the performance of fattening lambs for 12 weeks from weaning onwards. The results of this trial showed that DCP can replace maize grain in lambs fattening at a level up to 40% from weaning (at 42 day) until the age of 126 days, without observing significant differences in lambs growth.

In addition, no significant differences in the growth of lambs were recorded with the gradual replacement of maize grain by DCP at a level of 20% during the first 4 weeks after weaning, 40% for the following 4 week and 60% (total replacement of maize grain) for the final 4 weeks of lamb fattening.

Dairy cows

In a feeding trial carried out by Belibasakis and Tsirgogiannis (1996) 20 multiparous Fresian cows, 60–130 days post-partum, were allocated to two groups of ten cows, according to calving date, lactation number and daily yield and assigned randomly to one of two diets in a crossing-over design experiment. The two experimental diets contained either 20% DCP and 30% concentrate or 15% dried beet pulp, 8% maize grain and 27% concentrate, plus 50% maize silage (dry basis). The diets were offered individually, in tie-stalls, as a total mixed ration in equal amounts at 9:00 and 20:00 h to achieve ad libitum intakes. Dry Matter (DM), Metabolisable Energy (ME) and Crude Protein (CP) contents, milk yield, milk protein content and yield as well as content of milk lactose, total solids and Non-Fat Solids (NFS) were not significantly affected by the diet. In contrast DCP supplementation increased milk fat content (4.48 vs. 4.12%, p<0.05) and milk fat output (1.06 vs. 0.93 Kg day–1, p<0.05). No significant differences were observed in the serum concentration of glucose, total protein, albumin, globulin, urea, triglycerides, phospholipids, Na, K, Ca, P, Mg and Cl. Opposite, the serum concentration of cholesterol was higher (235 vs. 223 mg per 100 ml; p<0.05) when the cows were fed on the diet containing DCP.

Wethers

Two digestibility trials were performed in Greece using wethers to assess the nutritive value of DCP. In the first digestibility experiment carried out by Fegeros et al. (1995) 6 adult wethers of the local Karagouniko breed were used to determine the nutritive value of DCP. The diets consisted of 800 g of hay and 150, 225, 300, 375 and 450 g of DCP. The apparent digestibility of DM, Organic Matter (OM), CP, Ether Extract (EE), Crude Fibre (CF) and Nitrogen-Free Extractives (NFE) for DCP were 78.6, 82.7, 52.7, 82.0, 93.2 and 83.1% respectively. Energy content was estimated to be 1.66 Mcal of Net Energy for Lactation (NEL) per Kg of DM.

In a second experiment Karalazos et al. (1992) used 4 castrated rams with an average live weight of 87 Kg, which were allocated to 4 treatments according to a Latin Square design. The animals were fed 4 different isonitrogenous diets containing 0 (controls), 10, 20 and 30% DCP. Digestibility of CP, EE, NFE and Gross Energy (GE) in the diets did not differ significantly regardless of the level of DCP in the diet, whereas digestibility of DM and OM decreased significantly (p<0.05) in the treatment containing 30% DCP. In contrast, digestibility of CF (p<0.05) increased significantly in all diets containing DCP, compared to controls. Nitrogen retention by animals was not affected by the level of DCP in the diet. The results of this study show that DCP constitutes a feeding stuff of high energy value and can be used in ruminant rations up to the level 20% of DM of the diet, replacing equal amount of cereal grains.

ENSILING

Drying fresh citrus pulp is an expensive procedure. On the other hand, fresh citrus pulp, due to its high moisture content, cannot be stored for long. In this respect, ensiling is a sensible proposition for the conservation of citrus pulp destined for year-round animal feeding, particularly for the dry season when grass is scarce. DCP has been extensively studied with large ruminants, dairy cows (Wing 1974) and fattening calves (Hadjipanayiotou and Louka 1976), whereas work on Citrus Pulp Silage (CPS) with sheep appears to be limited. Due to the high water content of citrus by-products, it is more advantageous to mix them with other dry materials before ensiling (Ashbell et al. 1995; Scerra et al. 2001). Two experiments have been performed in Greece using ensiled citrus by-products. One employing CPS and the other utilising Ensiled Surplus Oranges (ESO).

Citrus pulp silage

In the first experiment reported by our team (Volanis et al. 2006) sixty-six 18 month-old lactating ewes of the local Sfakian dairy sheep were used to study the effects of feeding a CPS mixture on ewes milk yield and composition. 3 Kg of CPS mixture with by-products was offered daily to the ewes as experimental treatment, replacing part of the supplemental feed/pelleted alfalfa/oat hay diet given to the controls. Silage pH dropped from 4.79 before to 3.43 following ensiling. DM of silage was 25.6% lower at the end of ensiling (24.6 vs. 18.3%). The CPS (originating from orange-juice canning industry) proved palatable to sheep particularly due to its pleasant odour.
The effects of CPS on milk yield and composition are given in Table 1. Mean daily milk yield was 3% higher for controls not significantly though, but the situation was reversed (6.6% lower) when the 6% Fat Corrected Milk (FCM) yield was considered. Ewes fed CPS had 17% higher fat and 5.4% higher NFS content in milk (p<0.001 for both milk components). Treatment differences in ewes body weight were not significant during the experimental period. Results show that the inclusion of CPS in diets of lactating ewes is a viable proposition, particularly for the dairy breed of sheep whose milk is used in cheese manufacturing industry.

**Ensiled surplus oranges**

Appreciable quantities of fresh oranges are fed to animals every year (Gohl 1981). These quantities consist of either non-marketable oranges or marketable, which due to the formation of surpluses in a short period, cannot be utilised as fruits for humans or by the orange juice industry. All these surplus amounts of oranges, particularly during the rushing period, cannot be consumed in short time by animals and thus get mouldy and sour becoming useless as animal feed. The conservation of the excess part of surplus fresh oranges by ensiling is offered daily to the animals as experimental treatment, replacing the conventional ration of sheep, thus lowering the cost of production. Since milk from dairy breeds of sheep in Greece is conventional ration of sheep, thus lowering the cost of production. Since milk from dairy breeds of sheep in Greece is

![Image](https://via.placeholder.com/150)

**Table 2** Dry Matter, pH and load of yeasts and fungi in Ensiled Surplus Oranges before and after ensiling.

<table>
<thead>
<tr>
<th>Stage</th>
<th>DM (%)</th>
<th>pH</th>
<th>Yeasts and fungi*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before ensiling</td>
<td>25.0</td>
<td>4.10</td>
<td>2.0×10^6</td>
</tr>
<tr>
<td>After ensiling</td>
<td>21.0</td>
<td>3.75</td>
<td>4.5×10^6</td>
</tr>
</tbody>
</table>

* CFU g⁻¹ (Colony Forming Units)


**Table 3** Effects of Ensiled Surplus Oranges on daily milk yield and composition of dairy ewes.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Control</th>
<th>Experimental</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk yield (g day⁻¹)</td>
<td>769</td>
<td>680</td>
<td>*</td>
</tr>
<tr>
<td>FCM yield (g day⁻¹)</td>
<td>821</td>
<td>832</td>
<td>NS</td>
</tr>
<tr>
<td>Fat (%)</td>
<td>6.57</td>
<td>7.84</td>
<td>***</td>
</tr>
<tr>
<td>CP (%)</td>
<td>4.49</td>
<td>4.37</td>
<td>***</td>
</tr>
<tr>
<td>Lactose (%)</td>
<td>5.44</td>
<td>5.83</td>
<td>***</td>
</tr>
<tr>
<td>NFS (%)</td>
<td>10.8</td>
<td>11.1</td>
<td>**</td>
</tr>
</tbody>
</table>


**REFERENCES**


