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

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ABSTRACT

Citrus, orange in particular, is an important crop grown in Greece. Part of the fruit yield is used for making juice in canning industry, leaving citrus pulp as the main by-product. On the other hand sheep keeping is the main animal production activity in the area. Therefore the utilisation of citrus industry by-products as animal feeds for this sector suggests itself. Attempts have been made over the years in Greece to study the nutritive value of various types of citrus by-products as feeds for sheep. Firstly, a citrus canning industry by-product, namely Dried Citrus Pulp, has been studied in sheep nutrition. In addition, ensiling of fresh citrus pulp has been tried and characteristics of fermentation have been recorded. Ensiled Citrus Pulp was fed to small ruminants and performance of lactating animals, as well as, quantitative and qualitative traits of milk were assessed. Furthermore, the use of Ensiled Surplus Oranges was studied with lactating dairy sheep. Finally, the biotechnological upgrading of citrus pulp, protein enrichment in particular has been also attempted. Some sensible results emerged from these studies, among them, that ewes fed ensiled citrus feed tended to have higher fat content in milk. Results show that the inclusion of citrus by-products in diets of lactating sheep is a viable proposition, particularly for the dairy breed of sheep whose milk is used for cheese manufacturing industry in countries round the Mediterranean basin but also elsewhere.

Keywords: citrus pulp, dehydration, ensiling, feeding, milk quality, ruminants

Abbreviations: ADF, acid detergent fibre; **CF**, crude fibre; **CP**, crude protein; **CPS**, citrus pulp silage; **DCP**, dried citrus pulp; **DM**, dry matter; **EE**, ether extract; **ESO**, ensiled surplus orange; **FCM**, fat corrected milk; **FEDCP**, fermented dried citrus pulp; **GE**, gross energy; **ME**, metabolisable energy; **NDF**, neutral detergent fibre; **NEL**, net energy for lactation; **NFE**, nitrogen free extractives; **NFS**, non-fat solids; **OM**, organic matter; **SSF**, solid state fermentation

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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.

Received: 22 July, 2008. Accepted: 2 October, 2008.

Invited Mini-Review

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 ruminant 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 C_4 to C_{10} 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 lamps 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 Tsirgogianni (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 libidum* intakes. Dry Matter (DM), Metabolisable Energy (ME) and Crude Protein (CP) intakes, 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 blood 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 75, 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, 87.2, 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.

Table 1 Effects of Citrus Pulpe Silage on daily milk yield and composition of dairy ewes.

Variable	Control	Experimental	Significance
Milk yield (g day^{-1})	653	634	NS
FCM[a] yield (g day^{-1})	636	678	NS
Fat (%)	5.85	6.85	***
CP (%)	5.31	5.50	NS
Lactose (%)	4.72	4.66	NS
NFS (%)	11.5	12.1	***

[a]FCM: 6% Fat Corrected Milk yield

Source: **Volanis M, Zoiopoulos P, Panagou E, Tzerakis C** (2006) Utilisation of an ensiled citrus pulp mixture in the feeding of lactating dairy ewes. *Small Ruminant Research* **64**, 190-195, ©2006, Elsevier BV.

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 and subsequent feeding to animals at a later stage, would save them from deterioration, protect animal's health, and prevent problems from their disposal to the environment. They also have economic benefit for breeders since they constitute a cheap feed particularly during the dry summer when grassland is very limited in Southern areas of Greece. Intakes of fresh oranges about 40 Kg per day, have been recorded with dairy cows (Volcani 1956). It was also pointed out that, even with cattle, to avoid the danger of whole citrus fruits getting stuck in the oesophagus, oranges should be sliced before feeding.

In the second study carried out also by our research team (Volanis *et al*. 2004) 96 lactating ewes of the Sfakian sheep breed divided into two equal groups were used. 3 Kg of sliced orange silage mixture with by-products were offered daily to the animals as experimental treatment, replacing part of the maize grain/soybean meal/oat hay ration given to the controls. To the best of authors' knowledge data of composition of such material did not exist in the literature and were reported for first time in that work. DM, pH and load of yeast and fungi in the ESO are given in **Table 2**. Silage pH from 4.1 before dropped to 3.75 after ensiling. Such trend has been reported before for CPS by Martinez-Pascual and Fernadez-Carmina (1978). CFU's of yeast and fungi in silage were about 200-fold lower at the end of ensiling process. Elimination of moulds during ensiling of citrus pulp after 35 days ensiling fermentation has been reported by Weinberg *et al*. (1988). Silage DM was 16% lower at the end of ensiling. Cervera *et al*. (1985) reported high losses of DM (32%) in CPS. Ashbell *et al*. (1987) reported with CPS that most losses occurred within 10 days of commencement of fermentation and were attributed to gas release. Orange silage proved palatable to sheep particularly due to its pleasant odour.

Results for milk yield and composition of sheep fed ESO mixture are given in **Table 3**. Milk yield and composition were measured for a 6-week period. Overall daily milk yield was 12% higher for controls (p<0.05) but the situation was reversed for the last third of the lactation period. However, 6% FCM yield did not differ significantly. Ben-Ghedalia *et al*. (1989) showed that citrus by-products improved utilisation of dietary fibre, due to their positive effect on rumen microflora activity. Ewes fed orange silage had 16% higher fat content in milk (p<0.05). Treatment differences in ewes' body weight were not significant during the experimental period. Results showed that the inclusion of ESO to diets of lactating sheep is a viable proposition.

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

Stage	DM (%)	pH	Yeasts and fungi[a]
Before ensiling	25.0	4.10	2.0×10^4
After ensiling	21.0	3.75	4.5×10^2

[a] CFU g^{-1} (Colony Forming Units)

Source: **Volanis M, Zoiopoulos P, Tzerakis C** (2004) Effects of feeding ensiled sliced oranges to lactating dairy sheep. *Small Ruminant Research* **53**, 15-21, ©2004, Elsevier BV.

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

Variable	Control	Experimental	Significance
Milk yield (g day^{-1})	769	680	*
FCM yield (g day^{-1})	821	832	NS
Fat (%)	6.57	7.84	***
CP (%)	4.49	4.37	*
Lactose (%)	5.44	5.83	***
NFS (%)	10.8	11.1	**

Source: **Volanis M, Zoiopoulos P, Tzerakis C** (2004) Effects of feeding ensiled sliced oranges to lactating dairy sheep. *Small Ruminant Research* **53**, 15-21, ©2004, Elsevier BV

BIOTECHNOLOGICAL UPGRADING

The nutritional improvement of citrus pulp, protein enrichment in particular, has been also attempted in Greece. DCP was pasteurised for 4 h and fermented with cellulolytic and pectinolytic strains of *Trichoderma viride* and *Trichoderma reesei* in a bioclimatic chamber for 4 days of culture at 28°C and moisture level of 85%. The Solid State Fermentation (SSF) gave rise to a product called fermented-DCP (FEDCP) which had 3 times more CP (21% DM) and less Acid Detergent Fibre (ADF) and Neutral Detergent Fibre (NDF) content than the initial DCP (CP 6.8% DM) (Iconomou D, pers. comm.).

CONCLUDING REMARKS

The results of the above studies carried out in Greece indicate that citrus by-products, either in dried or ensiled form, can be fed to ruminants without negative effects on the performance of animals. Since citrus by-products are cheap raw materials widely available in Mediterranean countries but also elsewhere, its feeding value should be fully investigated with sheep and goats, the dominant farm animal species in the area. The conservation of fresh citrus pulp is very important for semi-arid areas, since in this way, roughage is made available during the dry summer when feed resources from pastures become scarce. Compared to drying, ensiling constitutes a more economical proposition since it does not require fuel for heating. Results from the above studies indicate that DCP, CPS but also ESO can replace part of the conventional ration of sheep, thus lowering the cost of production. Since milk from dairy breeds of sheep in Greece is not used in its raw state directly for human consumption, but all is destined for cheese production, its high fat and SNF content is greatly appreciated by the cheese manufacturing industry.

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