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SOLID participatory research from Spain: The use of agro-industrial by-products in dairy goats farms

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Summary

This document described the work conducted in two dairy goats farms to assess the suitability of using silage made from tomato and olive by-products (farm 1) and citric by-products (farm 2) on the overall feeding strategy of the farm. The work was conducted during 2013. Previous results (i.e. SOLID Deliverable 3.1. Desk-top review of novel feeds for inclusion in organic and low-input dairy production) demonstrated the potential of a range of by-products and underutilized sources as animal feeds and highlighted the need for additional information concerning certain by-product feeds that should be obtained through a strong farmer and stakeholder interaction in order to guide the future research.

On the first farm a significant proportion of the forage is grown at the farm and most of the grain has to be acquired from outside. No by-products are used currently in the feeding strategy. On this farm the use of tomato and olive silages was investigated as a replacement forage source.

On the second farm the use of agro-industrial by-products is totally integrated in the feeding system. In this case citric (orange and lemon) fruits and leaves from a nearby citric cooperative are used continuously throughout the year.

The agro-industry sector in Southern Europe provides a range of valuable by-products with potential to be used as feed for small ruminants; however, the high moisture content represents the main limitation for the successful and wide use of some by-products by the feeding industry. Ensiling represents a promising option: silages made with tomato and olive by-products may replace medium quality forage (i.e. oat hay) in dairy goat farms provided that the farm is within 50 km from the site of production of the by-product.

In farms using citric by-products with an external input of concentrate, the quality of the forage has been identified as the weak point in ensuring efficient milk production over the entire lactation period.

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1 Aims and Research question

The objective of the participatiry on farm work in south Spain was to assess the suitability of using locally avaiable agro-industrial by-products in dairy goats feeding. Normally local by-products are available in specific periods of the year, which makes appropiate storage critical. One of the research questions was the suitability of ensiling as a menas to preserve high moisture feeds. These objectives were addressed by interacting as much as possibekl with the farmers about the feeding practices used routinely.

2 Background

2.1 Research Background

The quantity and quality of available feed resources is a key determinant of total system output and overall profitability. Organic and low input dairy systems are unique in their high reliance on internal forage resources which will at least temporarily limit system productivity and inevitably may require production goals to be adjusted (Schiere et al., 1999, Zollitsch et al., 2004). This, together with increased volatility in feed prices, highlights the need for a broadening of feed resources and the utilization of novel feed components that are currently under-utilized. In addition, strategies that optimise the management of feed resources have potential to reduce the risk inherent to organic and low input feed supply chains (e.g. seasonality of pasture/ forage production). The need to addresses the potential multi-functionality of organic and low input dairy production systems has to be through assessing approaches that involve increasing the accessibility of feed resources to dairy farmers, and developing tools with the potential to optimise the management of internal resources.

Studies need to identify the availability of, and quantify the nutritional value of unconventional feed components, and this includes:

a. By-products from food and non-food processing industries (Molina-Alcaide and Yáñez-Ruiz, 2008).
b. Feeds from emerging industries in Eastern European countries, biofuel crops across Europe and wood industry in North Europe (FAO, 2012) and
c. the need to alleviate the deficit of protein crops in Europe (European Parliament Report, 2011)

Since the nutrition of the animal is a major factor influencing milk quality, and the high level of forage use in organic and low-input dairy production systems is beneficial to improving the 'healthiness' of the milk fatty acid profile in bovine and caprine milk (Chilliard and Ferlay, 2004; Dewhurst et al., 2006), it is important to assess the impact of these novels feeds on milk quality in the context of both adapted and improved dairy breeds.

The on farm work to be conducted in South Spain fits into the first category of feeds (a). A recent report from FAO (Wadhwa and Bakshireveals, 2013) reveals nearly 50% of all fruits and vegetables in the European Union go to waste, with losses occurring during agricultural production, processing, and distribution, in the supermarkets and by the consumers. Although an intense research effort is currently taking place to increase efficiency to minimize waste production (i.e. FP7 project Veg-i-Trade), there are some unavoidable losses that come from storage conditions, juice production and market requirements. This represents a significant annual volume of potential feed that can be incorporated into animal diets. The majority of fruit and vegetable wastes are highly fermentable and perishable, mainly because of high moisture (80−90%), total soluble sugars (6−64% in DM) and crude protein (10−24% in DM) contents. During the peak production or processing season, large quantities of these resources are available and cannot be consumed at the same location as they become available and thus become surplus and can cause environmental pollution. Therefore, suitable methods should be adopted to conserve such resources so that these can be fed to livestock throughout the year or specifically during the period of low green fodder production. The most commonly used methods for biomass preservation are drying or ensiling. An extensive literature is available on the nutritive value of a range of fruit and vegetable by-products for ruminants (Molina-Alcaide and Yáñez-Ruiz, 2008); however, the on-farm evaluation of a system that ensures sufficient supply together with environmental and economic assessment of its use in different scenarios is still lacking.

2.2 Farmers' background

The results obtained at CSIC from *in vitro* and *in vivo* nutritive evaluation of a selection of agro-industrial by-products (Yáñez-Ruiz et al., 2004; Romero-Huelva et al., 2012; Soto et al., 2015), demonstrated the promise of some of them as ingredients in the diet of dairy goats to reduce feeding costs and therefore increase sustainability. Two dairy goat farms that represent two different models were identified for the trials:

- **Farm 1: Study of the effect of including silages made with olive or tomato by-products in the diet of dairy goats in mid lactation**
  On the first farm a significant proportion of the forage is grown at the farm and most of the grain has to be acquired from outside. No by-products are used currently in the feeding strategy. On this farm the use of tomato and olive silages was investigated as a replacement forage source.
- **Farm 2: On farm assessment of the use of citric by-products in dairy goats.** On the second farm the use of agro-industrial by-products is totally integrated in the feeding system. In this case citric (orange and lemon) fruits and leaves from a nearby citric cooperative are used continuously throughout the year.

3 Methodology and data collection

3.1 Location of the farms

One trial (olive or tomato silages) was conducted on a farm located in the outskirts of Granada city. The second trial (use of citric by-products) was conducted in a farm located in the south-east of Spain (Vera: 37°15′N 1°52′W, Almeria) in a peculiar and strategic situation, as it is surrounded by a plantation of orange and lemon trees (700 ha, see Figure 3).

3.2 Description of Trial 1

The trial involved dairy goats and was designed to study the effect of replacing a proportion of oat hay in a standard diet used in the farm with either tomato wastes or olive by-product silage on intakes, milk yield and composition and rumen fermentation characteristics. The farm had 200 milking goats, and 60 were used for the experiment. Animals were randomly allocated to groups of 5 goats, with each group placed in single pen (5 x 5 m) with free access to water. Animals were cared and handled in accordance with the Spanish guidelines for experimental animal protection (Royal Decree 53/2013 on the protection of animals used for experimentation or other scientific purposes) in line of Vertebrates used for Experimental and other scientific Purposes (European Directive 86/609).

Two types of silages were tested: i) tomato fruit + straw (80:20 fresh weight basis) + 0.5 % formic acid and ii) olive cake + olive leaves + barley grain (45:45:10 fresh weight basis). These proportions were selected based on previous observations from silage making screening trial undertaken within CSIC. . The ingredients were weighed and thoroughly mixed in a feed mixer. The mix was then baled, individually wrapped with four to six layers of "bale wrap plastic" (25 micrometre stretch film). This was performed with a bale wrapper, using a bale handler with front-loader (**Figure 1**). The bales had dimensions of 1.5 m x 1.5 m x 1.8 m and weighed around 800 kg.

Figure 1. Making silage bale (by Pablo Rufino).

Figure 2. Detailed photo of tomato silage (by Ignacio Martin-García)

Silages were opened after 70 days of fermentation (Figure 2). Three experimental diets were formulated as follows:

i. Total Mixed Ration (TMR) containing Oat hay 40%, Alfalfa hay 20 %, Barley grain 12 %, maize grain 16 %, Soya 13 %, Molasses 6 %, mineral-vitamin mix 2 %.
ii. TMR in which 25 % of the oat hay was replaced by olive by-product silage (OS)
iii. TMR in which 25 % of the oat hay was replaced by tomato by-product silage (TS).

All proportions are expressed in fresh matter. The amount of feed supplied to the animals was sufficient to allow daily milk production of up to 2 kg per goat. All rations were supplied twice a day.

3.2.1 Experimental procedure

Four groups of 5 goats were randomly assigned to one of the three experimental diets (TMR, OS and TS), resulting in 20 animals per diet. After 28 day adaptation period to the corresponding experimental diet, the total diet intakes in each group were recorded over a 7 day periods for each group (n=4). Individual milk yield was monitored on two consecutive days and aliquots (5 %) collected for analysis of composition. On day 26, approximately 50 ml of rumen contents was collected from each animal before feeding, using a stomach tube attached to a vacuum pump and strained through a nylon membrane (400 µm; Fisher Scientific S.L., Madrid, Spain). The pH was measured, and aliquots were taken for VFA analysis.

Chemical Analyses

Dry matter (method 924.01), ash (method 942.05), ether extract (method 920.39), and N (method 984.13) in samples of the offered and refused diet, feces, urine and milk were determined according to AOAC (2005). The N values of feeds, refusals, feces and urine, determined by LECO procedure, were converted to CP by multiplying by 6.25. The analyses of NDF were carried out according to Van Soest at al. (1991) using an Ankom 220 Fiber Analyzer unit (Ankom Technology Corp., Macedon, NY) with α-amylase and were expressed exclusive of residual ash.

The farm was visited over a period of 3 months; visits were organized every fortnight as a norm with the exception of the sampling period that required daily visits.

3.3 Description of Trial 2

This trial was conducted from September 2013 to January 2014, although data collected for the entire year 2013 was used as described later. The main objective was to monitor a farm that currently uses agro-industrial by-products as part of the feeding strategy. We aimed at describing the overall farm strategy, focusing on feeding, and collect feed samples (including by-products) for nutritional analyses to eventually provide the farmer with information on how to improve such a strategy.

Fruits that are not appropriate for human consumption and branches + leaves from cleaning and pruning are provided free of charge to the farmer daily, and he offers them directly to the animals. In exchange, the manure produced on the dairy farm is provided to the citric company as organic fertilizer. Due to the mild temperature throughout the year in this region of Spain (18-28ºC) housing facilities are not needed. The farm is run by a family (2 members) and one long-term employee. Goats' milk is sold through a cooperative for cheese making.

Figure 3. Dairy goats farm in Vera, Spain (by Leticia Abecia)

3.3.1 Farm data description

The farm is characterised as low input dairy goat farm with two family members and one worker as staff. There are 196 dairy goats, 12 bucks (male goats) and 406 kids (young goats). The farm also has 5 rams and 80 ewes with 120 lambs. Total Milk production averages 95,350 litres per year. The farm cultivates 2 ha for oat cultivation that is used also for hay production.

3.3.2 Methodology

The farm was selected in coordination with CABRANDALUCIA. After a first visit on the 1st September, the farm was visited regularly every month for data and samples collection. Samples of feeds (including by-products) being used at the time of each visit were collected and transported to CSIC research facilities for DM, OM, CP and NDF analyses and short term *in vitro* incubations to estimate metabolizable energy content. The methodology adopted is as described in section 2.3. As part of the collaboration with CABRANDALUCIA researchers had access to milk production data and composition as well as animal weights (those in lactation) for every month of the year 2013.

As a result of the visits to the farm and the interviews with the farmer, it was possible to estimate the actual supply of each feed per animal and day (for those in lactation), which was then translated into the energy (ME) and protein (CP) supply. The milk production data, its composition and the animals' weights were used to estimate the nutrient requirements that were compared with the supply of feed available to assess:

i) To what extent animals' requirements were met and
ii) What was the contribution of the by-products at different times of the year.

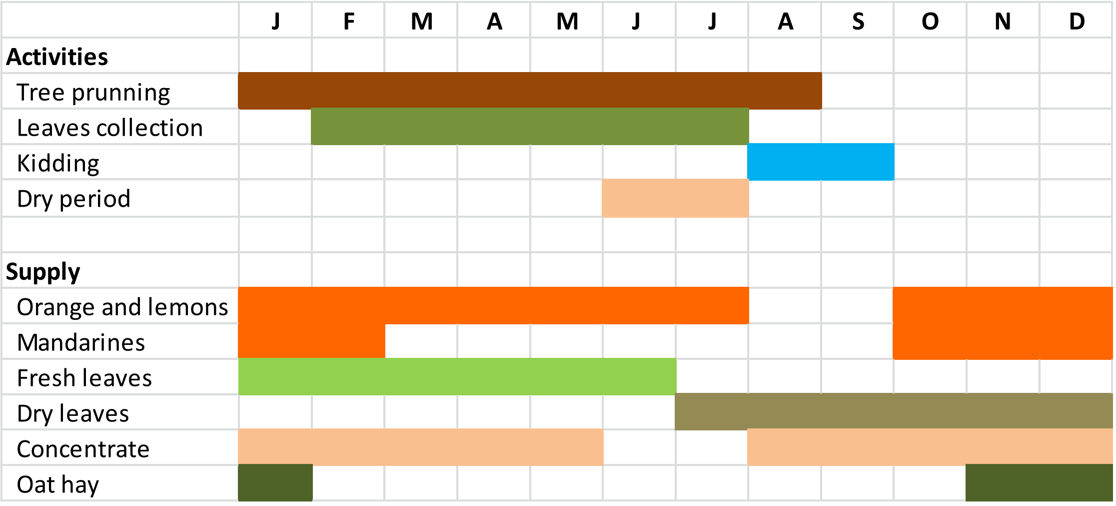

Figure 4. Calendar illustrating the main activities on the farm and the availability of different feeds in 2013.

4 Results and Discussion

4.1 Farm 1

Feeding both TSD and OSD diets resulted in higher DMI and an increase in milk production, although milk composition was unaffected (**Table 1**). Molina-Alcaide et al. (2003) and Romero-Huelva et al. (2012) did not find differences in DMI and milk composition in goats offered feed blocks (FB) containing olive cake and tomato wastes. The higher DMI observed in this trial may have been due to improved palatability of the silages used, compared to FB. No statistical differences were observed in total VFA concentration, probably due to the high variability induced by the collection system. Nevertheless the concentration of acetic acid decreased significantly when by-products were included in the diet.

Table 1. Effect of replacing oat hay in total mix ration (TMR) on intake, milk yield and milk composition and on rumen fermentation pattern.

	TMR	OS	TS	SEM	*P value*
DMI, g/d	916a	1426b	1286b	106	0.021
Milk characteristics					
Milk production, g/d	1010^{a}	1285^{b}	1387^{b}	86.3	0.007
Fat, g/kg	58.4	54.6	60.3	0.26	0.153
CP, g/kg	40.2	36.8	34.4	1.75	0.134
Lactose, g/kg	46.5	45.3	47.2	0.06	0.602
Total solids, g/kg	154	145	150	0.04	0.185
Rumen fermentation					
Total VFA, mM	38.6	30.0	32.3	3.46	0.459
Acetic , mol/100 mol	67.0a	64.8b	63.0b	0.36	0.005
Propionic, mol/100 mol	12.7	12.1	13.6	0.53	0.528
Acetic/Propionic	5.27	5.36	4.63	0.230	0.413

*Composition TMR: Oat hay 40%, Alfalfa hay 20 %, Barley grain 12 %, maize grain 16 %, Soya 13 %, Molasses 6 %, mineral-vitamin mix 2 %. OS: olive oil by-products silage; TS: tomato silage.
Means with different superscripts letters in a row significantly differ (P<0.05)

The literature available on the suitability of tomato and olive by-products in dairy farming is still limited and always involves the inclusion of such by-products as part of silage type forage. Ensiled wet tomato pomace used as a supplement in Comisana dairy ewes' diet did not modify milk yield or its gross composition (Di Francia et al., 2004). Similarly Weiss et al. (1997) reported that tomato pomace ensiled together with corn plants (total concentration of tomato by-product of 12 % on a DM basis) fed to lactating cows for 60 days did not modify milk production (35.5 kg/day) or milk composition (total fat and protein) as compared to corn silage diet. More recently, Abdollahzadeh et al. (2010) observed that when a silage comprising a mix of tomato and apple pomace (50:50) replaced alfalfa hay at three levels (0, 15 and 30%), and was offered to dairy cows for 63 days, milk composition was unaffected but there was a significant increase in milk production (19.9 vs 21.9 kg/day).

Based on these results it can be concluded that including tomato wastes and olive by-products silages in the diet of dairy goats could reduce feeding costs, while increasing DMI and milk production, and without compromising milk composition. However, to support such conclusions the costs associated with the collection and processing of the by-products would have to be evaluated. It was assumed that the silage would be made at the farm, which implies that the tomato or olive by-products would need to be transported there and then processed. To simplify the calculations, it was assumed equivalent nutritive values of the silage and oat hay (on a dry matter basis). Considering the costs of collection, transportation and silage making and an average price of oat hay in south Spain (0.14 €/ kg), we estimated that the use of both by-products is justified for a maximum distance of 50 km between the production site of the by-product and the farm. The shorter the distance, the more convenient. However, an alternative would be to centralize the collection and production of the silage for a number of farms to minimize the production associated costs. In that sense, the municipality of 'EL Ejido' (Almeria, Spain) has initiated a project to build a silage making site to produce silage made with a range of agro-industrial wastes produced in the area (http://www.hortoinfo.es/index.php/noticias/1629-ejido-reciclaje-30-07). El Ejido is one of the areas with highest concentration of greenhouse horticulture production in Europe and potentially can deal with 5,000 T of vegetable wastes annually. This project is currently a collaboration with our team at CSIC to further develop the technology to cover the range of materials that could be used and the use of different silage enhancing additives.

4.2 Farm 2

The analysis of the composition of the different citric by-products used in this farm revealed that the fruit had a low protein and high energy content (oranges, mandarins and lemons). The mix of branches and leaves had a surprisingly high content of protein, however it is likely that a substantial proportion of the N was associated with the fibre components and therefore had a low availability.

4.2.1 Analysis of the feeding strategy

Oranges, lemons, mandarins and leaves were offered throughout the year as illustrated in **Figure 5**. Based on the data collected through interviews it was estimated that on average animals were offered 2.3 kg (fresh matter) of fruits (it was not possible to differentiate between the three of them as they were normally offered mixed). The fruits were served in two large cages without any processing and the animals had free access to them during the day (**Figure 5**).

Figure 5. Goats with free access to citric fruits (by Leticia Abecia)

Figure 6. Goats consuming leaves and branches at the farm (by Leticia Abecia)

The harvest of the fruits and the pruning of the trees produced a considerable amount of leaves and small branches that are available from January to June. During that period fresh leaves were offered daily to the animals and the excess that was not consumed by them was left to dry outdoors and was then stored to be offered during the period July-December (**Figure 6**). Leaves and small branches represented the only forage source for the goats except when the weather did not allow the animals to visit the area where leaves and branched are kept. In those circumstances oat hay was provided. This occurred in 2013 during the months of January, November and December.

Table 2. Chemical composition (g/kg DM, unless stated otherwise) of the feeds used at the farm

	DM (g/kg)	OM	CP	NDF	ME
Oranges	415	960	85	127	6.45
Mandarines	154	960	62	154	6.29
Lemons	110	958	73	97	6.15
Fresh leaves	370	872	172	177	5.45
Dry leaves	916	812	125	285	4.48
Concentrate	855	951	176	212	9.98
Oat hay	908	924	53	330	6.25
Barley straw	939	970	17	433	5.22

DM: dry matter, g/100 g fresh matter; ME: metabolizable energy (MJ/100 g DM)

In addition to the supply of citric fruits and leaves, lactating goats were offered 1.25 kg concentrate daily during milking (split in 1/2 in the morning and afternoon).

As presented in **Figure 7** overall milk yield on the farm increased from September to November, then reached a plateau until January and showed a sharp decline through February. Milk fat content decreased from September to January, then increased gradually over the two following months and finally decreased towards the end of lactation (June).

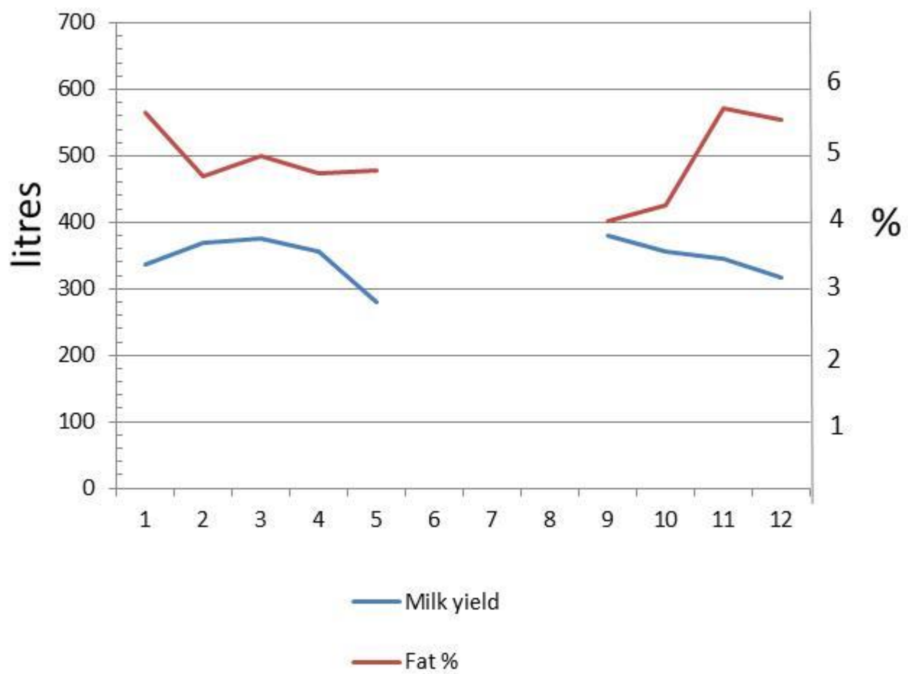

Figure 7. Changes in daily milk yields and milk fat content on monitor farm throughout the year (months 1 to 12).

Based on the data collected during the year on animal live weights, milk production and composition, energy requirements of the goats where estimated for every month (**Figure 8**). Likewise, using the information provided by the farmer and the composition analysis of the feed conducted in the CSIS lab, an estimation of the metabolizable energy supply (MJ per animal) was made for every month of the year. The yearly pattern of both requirements and supply shown in Figure 13 reveals that during some periods (first 3 months of lactation) the energy provided did not meet the requirements of the animals, while the opposite trend was observed for the rest of the lactation. A sharp decrease in supply was experienced in February. In an attempt to find explanations for this pattern, the supply of the different ingredients (**Figure 4**) provided some information. Given that concentrate and citric fruits are provided throughout the year and that their composition does not change, it is likely that it is the forage part of the diet what might be causing the changes in the nutrient supply. The farmer produced oat hay to be provided to animals when orange leaves and branches did not provide enough forage. However, the quality of the leaves and branches declines quickly during the drying process, and this may result in a deficient supply of structural carbohydrates. If this is not compensated by a provision of good quality oat hay it might result in insufficient supply of fibre, which may affect the production of acetic and butyric acids in the rumen and the subsequent decline in milk fat content (Murphy et al., 1982). Indeed looking at the composition of both dry leaves and oat hay, it may be concluded that fibre quality in the diet of the goats might not have been adequate. Also, excess in the supply of concentrate and citric fruits during the second part of the lactation might have occurred.

These results have been discussed with both the farmer and the nutritionist to implement more efficient feeding management for the coming year.

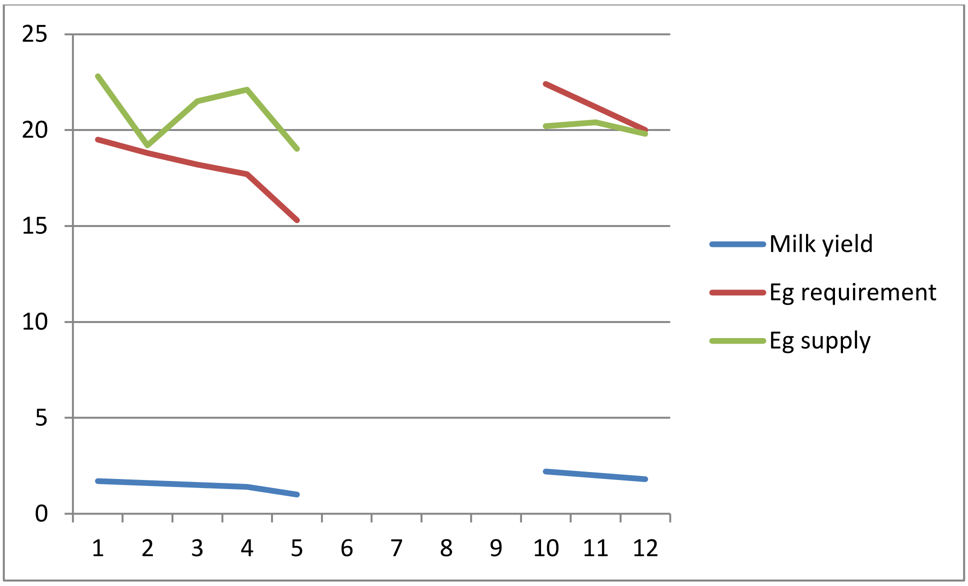

Figure 8. Estimation of the energy requirements and supply over the year 2013.

5 Conclusions/Recommendations

The agro-industry sector in Southern Europe provides a range of valuable by-products which have potential to be used as feeds for ruminants. However, they vary widely in their nutritional value and therefore the practical use in diet formulation can be challenging. The high moisture content represents the main limitation for a successful and wide use of some by-products by the feeding industry. This work has shown that ensiling tomato and olive oil derived by-products represent a valid strategy to maintain their nutritive value and ensure supply of these by-products throughout the year. Specifically silages made with tomato and olive by-products may replace medium quality forage (i.e. oat hay) in dairy goat farms provided that the farm is within 50 km from the site of production of the by-product.

In farms using citric by-products with an external input of concentrate, the quality of the forage has been identified as the weak point in ensuring efficient milk production over the entire lactation period. Frequent feed analysis of the main ingredients used on farm would ensure a more appropriate feeding regime to animals and overall profitability of the farm.

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