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Ruminal degradability, digestibility, energy content, and influence on nitrogen turnover of various Mediterranean by-products in fat-tailed Awassi sheep

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ABSTRACT

Livestock husbandry in the dry areas of the Mediterranean basin is facing scarcity and fluctuation of feed supply and feed prices. At the same time the local agro-food industry is expanding and its by-products might be used as alternatives to traditional feed resources, but their nutritional value is not well known. Therefore, four by-products typical for the Mediterranean area were tested *in vitro* ($n = 3$ per diet or feed), *in sacco* ($n = 6$) and *in vivo* ($n = 6$) either individually or in a proportion of 0.34 of the total diet. The test feeds (broken lentils, sugar beet pulp, tomato pomace and crude olive cake) were compared to a barley–wheat bran mixture (control). Forage (barley straw) made up proportionately 0.5 of the diet. For all experiments either rumen canulated or intact castrated male Awassi sheep were employed. The thirty sheep used in the *in vivo* experiment weighed on average 42 kg. The animals were fed 1.1 kg dry matter (DM)/day and had free access to water. Large compositional differences (g/kg DM) between the batches of test feeds used in the present study were found in crude protein (from 79 to 245; for olive cake and broken lentils), neutral detergent fiber (aNDFom; from 283 to 584; for broken lentils and olive cake) and non-fiber carbohydrates (from 109 to 436 for tomato pomace and olive cake and to broken lentils). Two feeds (tomato pomace and olive cake) were rich in ether extract; sugar beet pulp was rich in calcium. Broken lentils had the highest effective degradabilities (ED). Olive cake was lowest in ED of OM and aNDFom (0.39 and 0.32, respectively). Olive cake caused refusals of concentrate (lower proportionate concentrate intake compared with the control, $P<0.001$). The apparent nutrient digestibility of broken lentils and sugar beet pulp was similar ($P<0.001$) to the control and lower ($P<0.001$) for tomato pomace and olive cake. Metabolizable energy (ME; MJ/kg DM) was determined by various ways and always showed a very low value for olive cake (1–2). Broken lentils and sugar beet pulp had ME contents higher ($P<0.001$) than that of tomato pomace. The study showed that some by-products were promising as alternatives to traditional concentrate ingredients, while others, especially olive cake, might be only used at low levels.

Abbreviations: ADFom, acid detergent fiber; aNDFom, neutral detergent fiber; CP, crude protein; DM, dry matter; EE, ether extract; OM, organic matter; CF, crude fiber; ME, metabolizable energy; DMD, apparent dry matter digestibility; DOMD, apparently digestible organic matter in dry matter; GE, gross energy; ICARDA, International Centre of Agricultural Research in the Dry Areas; lignin(sa), lignin determined by solubilization of cellulose with sulfuric acid; OMD, apparent organic matter digestibility; OM_f, organic matter apparently fermented in the rumen.

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1. Introduction

Production of food from animal origin in Mediterranean countries was always constrained by the insufficient and fluctuating natural supply of feeds (Molina-Alcaide et al., 2003). Often this is caused by recurrent and severe droughts. Additionally, the price volatility in the major agricultural commodities, exacerbated during the food crisis of 2007–2008, has increased the general concern about the food security status of many developing countries (World Bank, 2008).

One option to overcome these problems is the use of more cost-efficient animal diets (Molina-Alcaide and Yáñez-Ruiz, 2008), for instance by employing agro-industrial by-products. Agriculture in the Mediterranean basin countries shares some common original features, like cereal cultivation, vegetables, pulses (*e.g.*, lentils), viniculture and tree farming focusing on olive and citrus (UNEP/FAO, 1977). The Mediterranean region comprises 0.98 of the total area for olive trees and 0.97 of the total olive production (Molina-Alcaide and Nefzaoui, 1996). Often the traditional mode of oil production by pressing is applied. Therefore, crude olive cake is a by-product occurring in large amounts (Sansoucy, 1985). The promotion of pulse cultivation is done since ages because of their agronomical benefits like nitrogen fixation and tolerance to high temperatures and their protein contribution to the diet (González and Andrés, 2003). Horticulture has gained importance more recently because of the favorable climatic conditions for many of these crops like tomato, pepper and artichoke. Principal by-products from the tomato industry are tomato pomace and whole waste tomatoes from culling. So far, by-products from tomato processing have been tested for animal feeding in dry form (Fondevila et al., 1994), ensiled with corn (Weiss et al., 1997) or with wheat straw and wheat grain (Denek and Can, 2006). When there is a surplus of production even food-grade or waste tomatoes are fed (Ammerman et al., 1963). In addition, some industrial crops from the Northern Mediterranean basin were later introduced to the Eastern Mediterranean basin for self-sufficiency reasons. This is the case for sugar beet even though it is a highly water demanding crop (Barnes, 2009). Sugar beet pulp is a low ligno-cellulosic and pectin rich feed for ruminants (Bodas et al., 2007). In Greece, sugar beet pulp is already used in ruminant diets at proportions of up to 0.30 of total diet (Iconomou et al., 1998) and in Spain and France as a feed partly replacing barley grain in fattening (Normand et al., 1999; Bodas et al., 2007).

Overall, the by-products, available in considerable amounts, are still under-utilized and not well known for their applicability in livestock nutrition. For some, information to be introduced efficiently in production systems is scarce (Gasa et al., 1989). The few studies available often propose individual options as feed supplements for small ruminants (*e.g.*, broken lentils, Surra et al., 1992; sugar beet pulp and molasses, FAO, 1985; Hadjipanayiotou, 1997; Bodas et al., 2007; tomato pomace, Fondevila et al., 1994; olive cake, Ben Salem and Znaidi, 2008; Molina-Alcaide and Yáñez-Ruiz, 2008).

As in-depth and direct comparisons among these feed options are missing, the primary objective of the present study was to simultaneously test several of the above mentioned by-products at high dietary proportions and in relation to a control diet. At the same time, the study will provide nutritional data to complement existing feed tables with data on new feeds or so far scarcely evaluated feeds, The investigation included measurements of ruminal degradability, total tract digestibility, effects on nitrogen balance. Eventually, various attempts to quantify their energetic value were made. In order to be able to distinguish among feeds, they were included into always the same basal diets at a high level and without balancing for presumed energy content.

2. Materials and methods

The study was carried out at Tel Hadya, the main research station of the International Centre of Agricultural Research in the Dry Areas (ICARDA) located near Aleppo, Syria. The experiments were carried out meeting the 'International Guiding Principles for Biomedical Research Involving Animals' as issued by the Council for International Organizations of Medical Sciences.

2.1. Experimental feeds

Four by-products generated either from food processing or from food grading were used as test feeds in this study. This included broken lentils (the offal of food-grade lentil production), dried sugar beet pulp (the residue of sugar production), tomato pomace (the residue from tomato processing) and olive cake (the residue from olive oil extraction). Broken lentils (red lentil, variety '*Idlib* 2-ICARDA') and dried sugar beet pulp were bought from local feed markets. The tomato pomace was purchased from a commercial tomato purée factory (Conserva, Edleb, Syria) directly after the production process and was immediately sundried for 3 days at ICARDA. The olive cake originated from the first press of green olives and included hull and kernels. It was purchased in fresh form from a traditional cold pressing factory (Afrin, Syria) and oven dried at 40 °C for 4 days at ICARDA. In exchange to these test feeds, barley grain (variety 'Arabi Abiad', from ICARDA's own cultivation), the most drought tolerant cereal, and wheat bran (from a local market) were employed as a mixture of these two feeds reflects a concentrate type common in the region. Further feeds used in all diets were cottonseed meal (protein supplement; from a local marked), sugar beet molasses (making the feeds more appealing; from the sugar processing and refining factory Gisr El-shougour at Edleb, Syria) and barley straw (forage part of the diet; from ICARDA's own cultivation; a feed typical to dry areas). All feeds were obtained as complete batches for the entire study. Those feeds most at risk to perish (tomato pomace and olive cake) were confirmed to be not contaminated with aflatoxins by Enzyme-linked immunosorbent assay (ELISA) before use.