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Feeding of by-products completely replaced cereals and pulses in dairy cows and enhanced edible feed conversion ratio

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ABSTRACT

When fed human-edible feeds, such as grains and pulses, dairy cows are very inefficient in transforming them into animal products. Therefore, strategies to reduce human-edible inputs in dairy cow feeding are needed to improve food efficiency. The aim of this feeding trial was to analyze the effect of the full substitution of a common concentrate mixture with a by-product concentrate mixture on milk production, feed intake, blood values, and the edible feed conversion ratio (eFCR), defined as human-edible output per human edible input. The experiment was conducted as a change-over design, with each experimental period lasting for 7 wk. Thirteen multiparous and 5 primiparous Holstein cows were randomly assigned to 1 of 2 treatments. Treatments consisted of a grass silage-based forage diet supplemented with either conventional ingredients or solely by-products from the food processing industry (BP). The BP mixture had higher contents of fiber and ether extract, whereas starch content was reduced compared with the conventional mixture. Milk yield and milk solids were not affected by treatment. The eFCR in the BP group were about 4 and 2.7 times higher for energy and protein, respectively. Blood values did not indicate negative effects on cows' metabolic health status. Results of this feeding trial suggest that by-products could replace common concentrate supplements in dairy cow feeding, resulting in an increased eFCR for energy and protein which emphasizes the unique role of dairy cows as net food producers.
Key words: organic, dairy cow, efficiency, by-product, feed conversion

INTRODUCTION

Global crop demands are predicted to increase about 100 to 110% by the year 2050 (from 2005 as baseline year) and concerns about future food security are rising (Godfray et al., 2010; Tilman et al., 2011). This reinforces pressure on livestock systems because animals are very inefficient in converting feed into animal products (Bradford, 1999). According to Cassidy et al. (2013), 89% of crop-produced calories fed to animals are lost and do not recur as human food in form of animal products. However, when fed human-inedible feed, livestock can provide a net gain in food supply (CAST, 1999). With their ability to convert human-inedible fibrous plant substrates into high-quality animal products, ruminants have always played a unique role in animal agriculture. However, the high performance levels of modern dairy cows have made it necessary to feed high amounts of grains and pulses to dairy cows, which also lead to an increase in the feed versus food competition between dairy cows and humans (Knaus, 2009, 2013).

Wilkinson (2011) introduced the concept of the edible feed conversion ratio (**eFCR**) to compare human-edible input versus output. Oltjen and Beckett (1996) were the first to analyze dairy cow rations in terms of food balance. Their results showed that, for cows receiving 50% concentrates, the human-edible food output in form of meat and milk was lower than the potentially human-edible input with feeds (57 and 96% for energy and protein, respectively). In other words, these cows consume more human food than they produce. In this debate, the potential of by-products to improve food balances of dairy production has been addressed several times (Eastridge, 2006; CAST, 2013; Gill, 2013). Bradford (1999) attributed the global supply of by-products within a year the potential to energetically support 500 million tons of milk production. According to Bocquier and González-García (2010), using by-products as feed is also a strategy to become less dependent on cereals and oil seeds, which will become more important in human nutrition in the future.

By-products strongly vary in their chemical composition, and their effect on milk yield and other production indicators depends markedly on the type and amount of the by-product included in the ration. In general,

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by-products differ from common concentrates mainly in their starch and fiber contents. Inclusion of by-products in dairy diets is discussed differently in the literature. For example, earlier studies reported higher forage DMI associated with greater milk yield of cows fed fibrous by-products versus starchy concentrates (Thomas et al., 1986; Huhtanen, 1993). However, other studies have observed unaffected milk yield despite higher DMI (Phipps et al., 1987; Huhtanen et al., 1995), whereas others reported either no effects on DMI and milk yield (Castle et al., 1981) or a lower DMI and unaffected milk yield (Alamouti et al., 2009). Various by-products have already been analyzed and tested as supplements in dairy cow feeding (Bernard and McNeill, 1991; Mowrey et al., 1999; Bampidis and Robinson, 2006). However, only limited information is available on the potential of by-products to increase the eFCR.

The objective of this study was to examine the potential of by-products to increase eFCR in dairy production. Therefore, a by-product mixture was substituted for a commonly used concentrate mixture in a feeding trial. It was hypothesized that under the conditions of Austrian organic dairy production, by-products as supplements can strongly improve eFCR, without negative effects on feed intake, production traits, metabolic health, and efficiency indicators. To ensure that the lower starch and higher fat and fiber contents of the by-product mixture had no negative effects on animal health, blood variables relative to metabolic status, liver activity, and acute phase response were analyzed.

MATERIALS AND METHODS

Experimental Design and Animals

The experiment was conducted as a change-over design with 2 consecutive experimental periods of equal duration at the organic farm of the secondary agricultural and forestry school Ursprung in the province of Salzburg, Austria (570 m above sea level, 1,250 mm annual precipitation, 8.5°C average annual temperature) between November 2013 and February 2014.

Thirteen multiparous and 5 primiparous Holstein cows, housed in a cubical housing system with Calan gates (American Calan Inc., Northwood, NH) for individual feeding, were randomly assigned to 2 treatment groups of 9 cows each, according to milk yield, days in milk, lactation number, and live weight. At the beginning of the experiment, cows had an average (± SD) milk yield of 27.5 ± 5.1 kg, 683 ± 53 kg of BW, and DIM and number of lactations averaged 108 ± 90 d and 3.1 ± 2, respectively. Prior to the experiment, all cows received grass silage and hay derived from permanent grassland at a ratio of 0.75:0.25 on a DM basis for ad libitum intake, and a maximum of 8 kg fresh matter of commercially available concentrates per cow and day via an automatic feeding station (based on the milk production of the previous week).

Each experimental period lasted for 7 wk, whereby the first 2 wk were used for diet adaptation, and the last 5 wk were used for measurements. Immediately after the end of the first experimental period, treatment groups changed and the adaptation time for the second experimental period started. The first week of the experiment served as adaptation time for the Calan gates. The experimental protocol was approved by the national veterinary authority Salzburg (file number 20403–25/2/324–2013).

Dietary Treatments and Feeding Procedure

Cows were fed diets containing the same forages but differing in their concentrate mixtures. The composition of the forage and the ingredients of different concentrate mixtures, as well as their estimated proportion of human edible contents, are shown in Table 1. The ingredients of the mixture for the control group (**CON**) were crops commonly used in Austrian organic dairy cow feeding. The experimental by-product concentrate mixture (**BP**) included only by-products from the human food processing industry, which were available in organic quality in appropriate amounts. Control and BP mixtures were obtained from a commercial feed manufacturer and composed to be isoenergetic and isonitrogenous. Both treatment groups received a forage mixture for ad libitum intake, consisting of 0.75 grass silage and 0.25 alfalfa hay on a DM basis. The forage mixture was prepared once a day and offered twice daily in an amount to ensure approximately 10% of fresh matter feed refusals. Grass for silage production was first-cut, harvested from 6.5 ha of perennial clover-grass (approximately 50% grasses and 50% clover), 3.5 ha of permanent grassland (about 50% grasses, 30% herbs, and 20% legumes), and 2.5 ha of perennial rye.

Due to unfavorable weather conditions in Austria in 2013, the first-cut of artificially dried alfalfa hay was purchased from Italy. Chemical composition of both concentrate mixtures and the forage mixture are shown in Table 2. In both treatments, cows exceeding a daily milk yield of 14 kg received the respective concentrate mixture in pelleted form at a rate of 0.4 kg of DM per additional kilogram of milk via an automatic feeding station. These quantities were adjusted weekly and cows received a maximum of 8 kg of DM concentrate per day.

Data Collection and Analytical Procedure

Cows were milked twice a day at 0600 and 1630 h in a 2 × 3 herring milking parlor. Daily milk yield and