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Research Article

Multiple Health and Environmental Impacts of An Innovative Livestock Feed Intake Diet

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Abstract

Mahjoub feedstock diet (MFD) is an innovation primed for livestock feed. This innovation in feed ingredients covers efficiency, profitability, environmental footprint, animal health, and welfare. This study is the first to evaluate whether manure nutrients, ammonia emissions and milk quality were affected by feeding cows with MFD compared to regular diet. We carried out a field experiment on-farm including four dairy cows to investigate the effects of the MFD feeding system on cow health, contents of dairy products, and manure composition. The results have shown excellent cow health with antibiotic-free husbandry for several years; a privileged fatty acid profile in dairy products, i.e., a major reduction in trans-fat with increased protein content and customary amino acid profile; and finally, a high C: N ratio in odorless manure. Furthermore, our methodology of approach was within the industry's conventional cost. Our cumulative results imply the preferential health and environmental performance of the feed intake diet used in the current research. Further research is planned and ongoing to deepen understanding of MFD effect on both environment and cow/human wellbeing.

Keywords: Mahjoub feedstock diet, milk quality, odorless manure.

Introduction

Humanity is struggling to create chemical-free, GMO-free, hormone-free, antibiotic-free, safely clean, high-protein nutritional food with low-to-neutral carbon and water footprints at a reasonable price [(1)]. Therefore, improving the sustainability of dairy operations is a current key goal in the dairy sector, and one critical task to increase sustainability is to reduce environmental consequences from dairy production [(2)]. Hence, when evaluating feedstuffs to establish their nutritional contents and inclusion rates in dairy rations, the environmental impact, as well as production responses, should be taken into account. In fact, tremendous effort was put into finding new livestock dietary formulas to tackle the above-enlisted challenges around the globe [(3,4)]. Cattles, and particularly dairy production systems, significantly contribute to green house gas (GHG) emissions and global warming mostly through the creation of methane (CH4) [(5)]. In fact, methane is the largest contributor to global warming from the dairy sector, with a 28 times higher impact compared to carbon dioxide (CO2) over a hundred-year period [6]. Therefore, the transformation of our production systems with a particular focus on lowering GHG emissions has gained priority [7]. In this context, lessening environmental impacts from dairy production is one critical task to improve sustainability of dairy operations. Thus, the environmental impact, as well as production responses, should be considered when evaluating feedstuffs and determining their nutritional values and inclusion rates in dairy rations. Yan et al. [8], demonstrated that one attribute of energy-efficient cows is that less methane is produced relative to the amount of energy consumed or milk produced. Other studies have shown that breeding for cattle with high feed efficiency may also result in decreased daily enteric methane generation, due to the strong genetic and phenotypic association between daily methane output and residual feed intake [9,10]. On another side, profitability will rise due to improved feed efficiency because feed expenses are the main expense on dairy farms. Feed efficiency are expressed in various ways, including feed conversion efficiency (milk output over feed intake). In theory, improved feed efficiency decreases daily methane production due to a lower methane per kilogram of dry matter intake (DMI) at a given production level [11], while decreased methane production (e.g., due to nutritional strategies) does not necessarily improve feed efficiency. However, experimental data are inconsistent on the link between residual feed intake (RFI) and methane emission, while research has primarily focused on beef cattle [12,13] rather than on lactating dairy cows [14]. Recent developments in livestock nutrition have primarily concentrated on three areas: improving our understanding of the nutritional needs of livestock, identifying the supply and availability of nutrients in feed ingredients, and developing the least expensive diets that effectively combine nutrient requirements and nutrient supply [15-17]. In line with this strategy, the main objectives of our applied research are to reverse the livestock conventional common practices from high multi-dimensional polluter into a low polluter sector with a low water footprint; improving the quality of protein and fatty acids profiles for animal and human better health and well-being, and reducing the overall cost compared to organic practices. To achieve the objectives of this project, nearly a decade worth of applied research resulted in the development of a new balanced feed intake diet composed of a clean fresh sprouted highly nutritional mix, namely Mahjoub Feedstock Diet (MFD), produced in soil-less vertical farming in a controlled environment. Neutral carbon footprint (NCF) and low water footprint (LWF) resulted into chemicals-free, hormones and genetically modified (GMO) free husbandry practice at a local facility in Damascus, Syria. This study is a continuation of our applied research, and it is worth mentioning that it is the first to evaluate whether manure nutrients, NH3 emissions and milk quality were affected by feeding cows with MFD.

Material and Methods

Mahjoub's feedstock diet

Mahjoub feedstock (MFD) diet is an innovation primed for livestock feed. This innovation in feed ingredients covers efficiency, profitability, environmental footprint, animal health, and welfare. All chemical and physical analyses were conducted in Cumberland Valley Analytical Services (USA) according to standard and accredited protocols. MFD, with Mahjoob's Intellectual Properties, is a clean fresh sprouted diet produced in a controlled-environment vertical farming powered entirely by clean renewable energy resulting in a neutral carbon footprint and a very low water footprint at a local facility in Damascus, Syria .

Animals and Treatments

We conducted our experiments in a randomized complete block design. We fed four "Holstein" cows (average 506 ± 100 kg) on MFD diet over a period of two years. For manure comparison only, we collected fresh manure samples from cows fed a local common basal diet-containing soybean as a control (CON) and compared its chemical and physical composition to fresh manure collected from cows fed on MFD .On the other hand, we compared the composition of milk-fat produced by cows fed on MFD to a world-renowned brand butter fat sample. MFD was prepared once a day in the morning and fed to cows four times/24h, namely at 7am, 13:00, 17:00 and 20:00. Notably, cows were free-stall most of the day with access to outdoor and fed through designated feeding box. Finally, cow bedding was made of dried odour-less dried manure . Sample Collection and Measurement - milk production and composition. Cows were milked 2x daily with milk yields average around the year approximately 25 liter/day. Milk samples were obtained by automated milking machine and collected into clean and steamed containers, with measurements performed within one hour at the laboratories of the National Commission for Biotechnology (NCBT), Damascus, Syria. GC-MS standard protocols were used for fatty acid analysis (Thermo Scientific, USA) while amino acid analysis was performed by amino acid analyser (Agilent, USA). All chemical and colorometric assays for total protein and manure analysis were performed using standard protocols at NCBT.

Results

Feed Diet Analysis

Chemical analyses were performed on Mahjoub's feedstock diet (MFD) (Table 1) .

Effect of Mahjoub's feedstock diet on Manure Nutrient Content. The characteristics of the manure samples from cows fed MFD and meal local common diet are shown in Table 2 .

Table 2. Characteristics of the manure samples from cows fed Mahjoub's feedstock diet and meal local common diet

Properties	Unit	Basis	Manure from Cows fed MFD	Manure from Cows fed CON
Dry matter	wt%	wet	17.96	17.86
Volatile solids	wt%	dry	86.64	80.70
Ash	wt%	dry	13.36	19.26
Carbon	wt%	dry	50.22	46.80
Nitrogen	wt%	dry	1.65	2.20
C/N	wt%	dry	30.40	21.27
Ammonia	wt%	wet	0.07	0.21
Fiber	wt%	dry	53.11	49.58
Calcium	wt%	dry	2.34	2.07
Phosphorus	wt%	dry	0.17	0.26
Potassium	wt%	dry	0.67	0.72
Sodium	wt%	dry	0.17	0.14
Chloride	wt%	dry	0.21	0.83
Iron	wt%	dry	0.011	0.012
Electrical conductivity	µS/cm	-	180	470
PH	-	-	7.7	7.25

MFD = Mahjoub's feedstock diet; CONT = fed basal diet containing soybean (meal local common diet)

Analysis of Protein and Fat in Milk Products

We compared the amino acid (AA) profile between MFD and cow milk to explore the possible cow/rumen conversion of AA in vivo (Fig 1). To study the effect of MFD on fat profile, we compared the fat contents in milk-fat from MFD-fed cows to a globally well-known butter brand (Fig 2) .

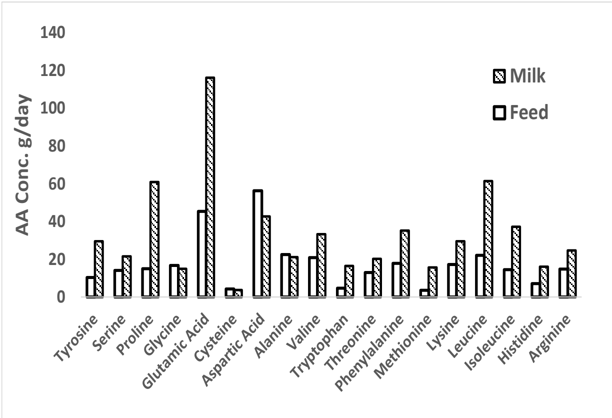

Fig. 1. Comparison of amino acid concentrations between the original MFD (g/day of feed intake) and cow milk (g/day produced) fed on MFD.

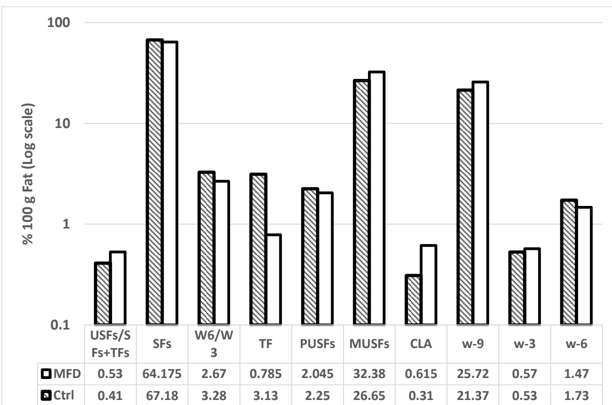

Fig. 2. Fatty acids composition in average milk fat from cows fed on MFD in comparison with a renowned fat brand. USF: unsaturated fat, SF: saturated fat, TF: trans-fat, ω9: omega 9, ω6: omega 6, ω3: omega 3, PUSF: polyunsaturated fat, MUSF: monounsaturated fat, CLA: conjugated linoleic acid.

Discussion

MFD composition

Results showed several privileged characteristics of MFD when compared to conventional cow feed diets [18] (Table 1) explicitly; high protein, low fat, low volatile fatty acids (VFA), high soluble protein SP/crude protein CP, neutral dietary cation-anion difference (DCAD), low starch, high acid detergent fibers (ADF), and near neutral pH. This composition may reflect the sprouted non-stiff format of MFD and makes it a unique high protein diet, which might positively reflect on cow health .

Manure Composition

Despite the fact that manure is a valuable fertilizer, it has the potential to harm the environment in terms of odor, air, soil, and water quality [19]. As various types of gases (e.g., NH3, greenhouse gases, and H2S) are created from manure via microbial fermentation or chemical changes, farm odor and a reduction in air quality at stalls and during manure storage before application to the field may occur [20]. It is worth knowing that the amount of gas generated by manure is determined by both internal and external factors. External influences include chemical forms of nutrients and nutrient concentrations, temperature, humidity, wind, bedding, manure storage system, and so on. Internal factors may include the cow genetic makeup and the microflora residing in their intestines .

In our study, we assessed changes in manure characteristics as well as potential gas emissions from manure. In fact, feeding the cows on MFD diet tended to increase manure pH compared to controls (7.7 vs.7.26) (Table 1). The content of organic matters was greater for MFD versus CONT, without a difference in dry matter (DM). It is worth noting that manure nitrogen content was lower for MFD versus CONT (1.65 vs. 2.2 %), and this could be a factor that potentially lowers NH3 emissions from manure because manure N, in the form of urea, contributes to NH3 emitted from manure [21,22]. Our results showed that the cumulative ammonia production for MFD was lower than its production from CONT by a factor of three (0.07 vs. 0.21 %). The degree of the decrease in NH3 emissions by MFD in this study is similar to the decrease observed when feeding cows on a low-protein diet [23]. Thus, our data demonstrate that the NH3 -emitting potential of manure can be reduced using MFD without decreasing dietary protein content, as the high protein content of MFD was not associated with high manure nitrogen, as one would expect.

Table 1. Chemical analysis of Mahjoub's feedstock diet

Properties	Unit	Basis	MFD
Dry matter	wt%	wet	24.9
Ash	wt%	dry	5.56

Crude protein	wt%	dry	28.2
Soluble Protein	wt%	dry	17.6
Crude fat (fat ether extract)	wt%	dry	2.83
Starch	wt%	dry	11.8
Starch	wt%	NFC	44.0
Soluble Fiber	wt%	dry	9.51
Soluble Fiber	wt%	NFC	35.4
Volatile fatty acids	wt%	dry	5.58
Lactic Acid	wt%	dry	2.20
Lactic Acid	wt%	VFA	39.4
Acetic Acid	wt%	dry	3.38
Propionic Acid	wt%	dry	0.19
Ammonia	wt%	dry	17.3
Lignin	wt%	dry	4.24
Soluble Fiber	wt%	dry	9.51
Non Fiber Carbohydrates	wt%	dry	26.8
Non-Structural Carbohydrates	wt%	dry	13.4
Acid detergent fibres	wt%	dry	25.1
Total digestible nutrients.	wt%	dry	68.4
PH			6.68

MFD= Mahjoub's feedstock diet; NFC= non-fiber carbohydrate; VFA= volatile fatty acids

The C/N ration in manure from MFD-fed cows was profoundly higher compared to manure from locally fed cows (30.4 vs. 21.27), while total nitrogen was lower (1.65 vs 2.2) and fiber content was close (53.11% vs. 48.58%), compared to manure from locally common fed cow. The profoundly lower electrical conductivity (180 vs. 470 µS/cm) and higher pH (7.7 vs 7.25) in MFD-fed compared to locally fed cows may enhance the applicability of the fresh manure from the former as a proposed soil substrate replacement. Worth to mention, the low ammonia concentration may have resulted in a near-no odour of manure .

Amino Acid Profile

Our results show a major increase in several amino acids upon feeding on MFD, specifically two essential AA (proline and glutamate), and leucine, a non-essential AA. Interestingly, these three previous AAs were proposed to play a main role in regulating and enhancing the immune response in both cows and humans [24,25]. In fact, it is well known that amino acids regulate the activation of many immune cells including T and B lymphocytes, natural killer cells and macrophages, in addition to controlling gene expression and the production of antibodies and cytokines (24). Nevertheless, one major finding about MFD-fed cows was the antibiotic-free wellbeing of the four cows in study over the last two years. This wellbeing is supported by physical in addition to biochemical analyses of several cow plasma biomarkers, all of which were continuously within reference ranges throughout the study (data not shown).

Fat Profile

The results showed several excellent features of the MFD on human health and wellbeing [26], including: slightly higher unsaturated fat and lower ω6/ω3 ratio compared to brand fat, a favourable profile in many health compromised situations including heart disease [27,28]. More importantly, fat from MFD contained substantially favourable lower trans-fat (TF) in MFD-milk fat compared to the brand fat (0.79 vs 3.13, respectively). In fact, previous research proved a direct link between TF and many diseases including cardiovascular, breast cancer and disorders of nervous system, etc [29]. Additionally, MFD-fat contained two fold levels of conjugated linoleic acid (CLA) in comparison to the brand fat (0.62 vs. 0.31, respectively). CLA has several beneficial health effects as it reduces body fat and consequently alleviates the risk for cardiovascular diseases and cancer. In addition, CLA modulates immune and inflammatory responses as well as improves bone mass [30]. Finally, both saturated C15 and C17 were markedly higher in MFD-fed cow fat compared to brand (C15; 0.86 vs. 0.40 g/100g fat) and (C17; 0.87 vs. 0.42 g/100g fat), respectively. C15 odd saturated fatty acids are linked to supporting metabolic and heart health, while both C15 and C17 fatty acids are associated with lower risks for cardiovascular diseases and mortality [31,32]. Taken together, the MFD-milk fat profile suggest an enhanced human wellbeing.

Conclusion

This study was the first to evaluate whether manure nutrients, NH3 emissions and milk quality were affected by feeding cows with Mahjoub's feedstock diet. Our results show a major increase in several amino acids in the milk of cows fed with MFD, which we propose to play a main role in regulating and enhancing the immune response in cows. Indeed, this could be supported by the fact that cows fed on MFD were antibiotic-free well-being for many years. On another hand, our results indicate that the NH3-emitting potential of cow manure were reduced by MFD without decreasing dietary protein content. Hence, a beneficial goal was achieved without jeopardizing the cow immune response relying on adequate protein concentration in the diet. Finally, the low ammonia values in MFD-fed cow manure, low total nitrogen, high fiber compared to local common-fed cow manure, low electrical conductivity and alkaline pH, will enhance the applicability of the fresh manure from MFD-fed cows as a proposed soil substrate replacement and may have resulted in a near-no odour of manur. More studies on the long-term incubation of manure will be necessary to understand H2S emissions during manure storage. In this context, further research is planned and ongoing; our preliminary results show predictable privileged characteristics of MFD on both environment and cow/human wellbeing.

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Competing interests:

Authors declare that they have no competing interests.