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Optimizing ruminant production systems for sustainable intensification, human health, food security and environmental stewardship

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Abstract

Whereas the contribution of ruminants to human civilization remains unequivocal, there are concerns regarding the unintended negative consequences of rearing these animals for food. These concerns range from the ruminant's contribution to greenhouse gas emissions to negative impacts of its products on the health of consumers. Rearing ruminants for food is thus seen as the root cause of ills such as climate change, species extinction, deforestation, food insecurity, cardiovascular disease, obesity, cancer and diabetes. Indeed, critics of ruminant production envision a future where humanity does not have to rely on animal products for food. They are convinced that this would be the panacea to food and nutrition insecurity, environmental pollution and meat-induced nutritional disorders and diseases in humans. The critics seem to be unaware of the wide diversity of ruminant production systems in use as well as the array of benefits that can be derived from these enterprises. For instance, there are large human communities that inhabit climatically hostile areas, which have no food crop production potential. Food and nutrition needs of these communities are largely dependent on nourishment provided by products and income derived from ruminants and other herbivores. The aim of this review article is to interrogate the validity of the concerns around the use of ruminants for food and highlight appropriate strategies and technologies that may be applied to mitigate some of these challenges. We conclude that solutions already exist that have the potential to deliver efficient, environmentally friendly and consumer-conscious ruminant production systems based on high standards of animal welfare. Such sustainable production systems will ensure that ruminants continue to play a crucial role in food and nutrition security of humans as they have done for millennia.

Keywords

Ruminants, environment, human health, food security, meat, climate change

Introduction

According to the United Nations (2015), the global human population is expected to breach the 9 billion mark by the year 2050. It is thus anticipated that meat consumption per capita will continue to increase. The consumption of animal products also tends to increase with per capita income (Schroeder et al., 1996). Thus, as incomes continue to rise so will the demand for animal products. Indeed, Delgado (2003) reports that the share of meat consumption in developing and emerging nations continues to increase in response to economic growth and prosperity. The FAO statistics predict a per capita meat consumption of 37 kg by the year 2030 in developing countries, up from 26 kg in the year 2000. This figure pales into insignificance when compared to meat consumption in developed countries, which peaks at 125 kg per capita in the United States (FAOSTAT, 2015). The rise in demand for animal products will undoubtedly put pressure on the environment since meat and meat products account for 4–12% of the impact of consumer products on global warming (Tukker et al., 2006). In addition, high intake of saturated fats associated with ruminant meat consumption is thought to be one of the causes of coronary heart disease in humans (De Smet and Vossen, 2016). There is global concern regarding the negative environmental and health effects (real or imagined) associated with ruminant meat consumption (Smil, 2002).

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Consequently, a number of governments have designed programs that integrate environmental and human health concerns into national dietary guidelines with particular attention to the consumption of meat (Smil, 2002). Critics advocate a ban on ruminant production as a solution to food and nutrition insecurity, environmental pollution and meat-induced nutritional disorders and diseases in humans. The objective of this review article is to interrogate the concerns around the use of ruminants as a source of food and highlight appropriate strategies and technologies that may be used to address some of these concerns. We believe that banning of ruminant production for food is a self-defeating course of action that will reverse the gains made in meeting the demand for high-quality food from a rapidly growing human population. We discuss the changes that may be necessary in order to ensure that ruminant production systems deliver efficient, environmentally friendly and consumer-conscious ruminant production based on high standards of animal welfare.

Role of ruminant animal products in food and nutrition security

Just over 14% of the global human population does not have access to adequate dietary protein and energy (FAO, 2009) while an even greater proportion (approximately 29%) suffers from micronutrient deficiency (Micronutrient Initiative, 2009). Approximately 2.6 million years ago, animal products became a significant part of the prehuman diet, and for a good reason. Meat and milk contribute to household food and nutrition security as sources of essential macro- and micronutrients (Mlambo and Mapiye, 2015) that have a higher biological value (i.e. highly digestible and found in a proportion similar to that required by the human body) when used as human food compared to plant-based foodstuffs. These food products are highly concentrated sources of essential amino acids (AAs), minerals and vitamins, which are critical human food components (Godfray et al., 2010).

Ruminant products contain a large proportion of essential nutrients that may be deficient in cereal grains such as maize, sorghum, millet and wheat (Mapiye et al., 2015). The consumption of small quantities of meat can correct nutrient deficiencies in cereal-based human diets. In addition, animal proteins are highly digestible and metabolized more efficiently than plant proteins (De Boer et al., 1994). As a result, an increase in the supply of ruminant products ensures food and nutrition security as well as dietary diversity. In drought-prone areas, ruminants and other herbivores are chief sources of food because the erratic rainfall patterns in these areas make these regions unsuitable for food crop production (Mlambo and Mapiye, 2015). In addition, the monetary income from sales of live animals and animal products also contributes to household food security. In fact, Kirsten et al. (1998) report that it is only when agricultural production has generated substantial monetary income or has enabled substantial reduction in household food expenditure that improved nutritional status of households is observed.

Ruminant production: Threats to food and nutrition security

Potentially, ruminant production negatively affects food and nutrition security through a variety of ways that include (1) the use of feed made up of grains and other ingredients (in feedlot and dairy animals) that can also directly serve as human food, (2) the use of land suitable for production of food crops to produce feed for ruminants and (3) the low feed conversion efficiency of ruminants into human-edible products. It is for these reasons that the net contribution of ruminants to food and nutrition security is questioned. We now review these negative impacts and explore how ruminant producers may mitigate these challenges.

Competition with humans for food

A question often asked by those who view animal agriculture with suspicion is whether animals compete with humans for food and by extension whether abolishing animal agriculture may result in better food and nutrition security (Mottet et al., 2017). Those who thrive on sensationalism tend to frame this question differently: Do animals take food out of people's mouths? Are livestock on our plates or eating at our table (Mottet et al., 2017)? Whichever way this question is asked, it requires producers to ponder the consequences and contributions of ruminant production to food and nutrition security. When reared as nature intended, ruminants should offer very little competition to humans for food because they simply prefer to consume grass and other fibre-rich forages. A large proportion (86%) of approximately 6 billion tonnes of dry matter consumed by livestock annually is not human-edible (Mottet et al., 2017). Indeed, feedlot beef production, criticized for using grains and seeds that are suitable for human consumption, accounts for only 7% of global beef production, with the remaining 93% coming from feeds that humans cannot use as food (Godfray et al., 2010). Since humans have little capacity to breakdown cellulose, it also means we cannot use it directly as a food source. Cellulose, one of the most abundant biomolecules on this planet, is composed of glucose molecules that, theoretically, could be useful as an energy source for humans in the same way that glucose from starch is readily used for this purpose (Cheeke, 2004). However, no mammal produces the enzyme cellulase that is required to breakdown cellulose, therefore, humans cannot effectively use grass as a direct food source. Ruminants take advantage of a resident microbial population to convert cellulose into tasty, highly nutritious animal products that are in turn used by humans as food (Mlambo and Mapiye, 2015). When used as converters of fibre, ruminants provide a unique and complementary pathway to improve food supply. As such, the role of ruminants in the bio-economy, as converters of forages, crop residues and agro-industrial by-products into high-value animal products and services, remains critical in the mitigation of food and nutrition insecurity in the face of increasing human population. Under this production system, it is difficult to see how a ban of ruminant production can possibly improve food and nutrition security for a rapidly growing human population.

However, ruminants are not only reared on natural pastures but also on cereal grains and edible legume seeds like peas, soybeans and lentils, depending on desired production level. Indeed, intensive production systems such as feedlots and dairying use animals of very high productivity with high nutrient requirements (Lemairea et al., 2014). Unfortunately, pastures alone do not have sufficient nutrients to support such high levels of production (Cheeke, 2004), thus farmers use cereal grains and legume seeds to meet the animals' energy and protein requirements, respectively. These feedstuffs can be consumed directly and utilized with greater efficiency by humans. Thus, a unit weight of cereal grains or legume seeds will directly feed more people than when used as an animal feed to produce meat and milk for human consumption (Cheeke, 2004). In addition, using these grains for animal feed increases their demand on the world market (Mnisi and Mlambo, 2018), resulting in higher prices that are unaffordable by resource-poor members of society. This practice results in the conversion of maize and soybean into premium animal products that are beyond the reach of the poor and vulnerable members of society. Ruminants are also less efficient when converting grains and seeds to animal matter compared to simple non-ruminants and non-ruminant herbivores (Godfray et al., 2010). It is, therefore, easy to see why certain sections of society view ruminant production that is based on cereal grains and legume seeds as unethical because it negatively affects food and nutrition security, particularly of the poor members of society. It can, therefore, be argued that in these production systems, ruminants do 'take food out of people's mouths', but it is also important to remember that there are very few human societies that are content to survive solely on maize grain and soybeans. With improvement in economic status, households tend to include more animal products in their diets. While scholars often laud the relatively greater efficiency with which pigs and poultry convert feed into human-edible products, it is important to remember that these animals consume a much higher share of human-edible grains, which are grown on land that is also suitable for growing food crops (Cheeke, 2004).

One way to resolve the problem of possible competition between humans and animals for food is to identify and nutritionally evaluate non-conventional feed resources with no direct food value for humans for use in ruminant production systems (Cudjoe and Mlambo, 2014; Ramsumair et al., 2014). Another approach is to optimize the use of natural and cultivated pastures so that they can support higher levels of productivity in dairy and beef cattle thus reducing dependency on cereal and legume grains. The use of derived vegetation indices and cover fraction to estimate aboveground biomass in rangelands environments (Fajji et al., 2017) can be another important tool to monitor and evaluate the ability of natural pastures to support ruminant production. Several studies prove the utility of rangelands as sources of feed for ruminants (Tefera et al., 2007, 2009).

Competition with crops for land

Godfray et al. (2010) contend that there is some evidence that more people could be supported from the same amount of land if they were vegetarian. This is because the conversion efficiency of plant matter to animal matter is lowly 10% (Godfray et al., 2010). Intensive ruminant production systems that use cereal grains and other nutrient-dense feed resources do compete for land with crops. The land used to produce food crops must also produce grains for feeding intensively reared ruminants. It is, therefore, true that intensively reared ruminants do compete for land with crops resulting in food insecurity especially in developing countries where food surpluses are rare. However, as long as the diet of these animals is grass, such as in extensive production systems, the low feed conversion efficiency should not be a major concern, given that humans lack the capacity to use grass as a direct food source. In extensive production systems, ruminants tend to utilize land that is not suitable for food crop production because of either low soil fertility or erratic rainfall patterns. This has the effect of increasing the land area that is used to produce food for human consumption. Extensively reared ruminants also utilize agricultural by-products (such as crop residues that remain after the harvesting of grains or industrial by-products) that would be of no direct food value for humans, thus addressing food and nutrition insecurity as well as waste disposal challenges. Indeed, integrated crop–livestock farming systems have been a permanent feature of agriculture in many countries (Lemairea et al., 2014). Ruminant production thus has the capacity to provide humans with animal protein without interfering with food crop production, especially when reared extensively.

Ruminant production – Environment nexus

Greenhouse gas emissions

While the utility of ruminants as converters of roughages and crop residues into human food is unequivocal, an environmental problem arises from the same digestive processes that are required to turn these fibrous materials into animal protein. Ruminal microbial fermentation produces two major greenhouse gases (GHGs), carbon dioxide (CO_2) and methane (CH_4). In addition, CO_2 from land use and its changes (feed production and deforestation) and nitrous oxide (N_2O) from manure and slurry management are also sources of GHG anthropogenic emissions associated with ruminant production (Opio et al., 2013). Enteric gaseous emissions are produced in large quantities when ruminants are reared on fibre-rich forages as opposed to grain-based diets. Consequently, feeding ruminants with feedstuffs that are not directly used by humans contributes to better food and nutrition security, but this may be at the expense of environmental health. However, the use of grain-based diets in feedlot production systems reduces enteric CH_4 emissions but raises the demand for grain on the world market as already discussed. Animal scientists and producers have responded to this challenge by identifying and evaluating strategies that mitigate enteric CH_4 emissions when animals are reared on natural pastures. Enteric CH_4 production represents a major (about 4–10% of gross energy intake) energy loss from the diet offered (Opio et al., 2013). As such, it is not that difficult to convince ruminant farmers to do more to reduce CH_4 emissions because if they succeed, it would increase the efficiency of ruminant production while at the same time protecting the environment.

Several strategies to mitigate enteric CH_4 gas emissions such as herd management, diet and nutrition management and rumen microbial manipulation have been proposed (Eckard et al., 2010). Herd management involves the selection of animals with higher feed utilization efficiency and, therefore, lower enteric CH_4 emissions. The strategy also includes reducing the number of unproductive animals in a herd (Smith et al., 2007) to improve profitability and reduce CH_4 emissions. Diet and nutrition management is the most preferred approach due to its cost-effectiveness and ease of application. This strategy includes improving forage quality, using dietary supplements (e.g. dietary oils, probiotics and enzymes) and use of plant secondary compounds such as tannins and saponins (Beauchemin et al., 2008). Indeed, Rangubhet et al. (2017) demonstrated the suppression of enteric CH_4 emissions upon including phytochemicals from spent mushroom substrate in diets for Holstein cows. However, most phytochemicals do not selectively depress the activity of methanogens in the rumen (Goel and Makkar, 2012) thus tend depress overall ruminal microbial fermentation activity. Rumen microbial manipulation is a strategy where the population of rumen methanogens is reduced via the introduction of competitive (acetogenic bacteria) or predatory microbes (bacteriophages), or through vaccination in order to reduce methanogenesis (Eckard et al., 2010).

Concerning CO_2 as a GHG, it should be noted that respiration and ruminal fermentation are not a net source of CO_2 because these emissions are part of a rapidly cycling biological system. The plant biomass that is consumed by ruminants is created via photosynthesis using atmospheric CO_2, and animals emit this CO_2 back into the atmosphere. While the carbon found in CH_4 is similarly derived from plant biomass, the problem is that it is converted into CH_4, whose global warming potential is 23 times that of CO_2 (Ugbogu et al., 2019) and cannot be sequestered by plants during photosynthesis.

Deforestation

A major ecological disaster associated with ruminant production is deforestation for pasture establishment as ruminant producers battle to keep up with increasing demand for animal products. The problem with this practice is that it incapacitates forests' role as a component of the global carbon cycle since they are part of terrestrial ecosystems that remove about 3 billion tons of anthropogenic carbon annually (Canadell and Raupach, 2008). However, the most common reason for clearing forests is not for ruminant production but for food crop production for humans (Cheeke, 2004). The second most common reason for clearing tropical forests is commercial timber harvesting, while cattle ranching only comes third as the cause of deforestation (Cheeke, 2004). Nevertheless, deforestation is a major contributor to GHG-driven climatic changes because it results in higher atmospheric CO_2 levels. It also exposes the soil leading to release of gases into the atmosphere. Solutions to this environmental problem include the establishment and use of fodder banks for feeding ruminants. Fodder banks mitigate against climate change because planted trees provide additional carbon sinks capable of sequestering anthropogenic carbon and thus reducing its atmospheric concentration (Atangana et al., 2014). In addition, the leaves and fruits from these trees tend to be of better quality compared to tropical grasses (Cudjoe and Mlambo, 2014; Mlambo et al., 2004) and thus will result in lower enteric CH_4 emissions when used as feed for ruminants. The tree leaves also contain phytochemicals such as phenolics and saponins that are known for their anti-methanogenic potential (Goel and Makkar, 2012; Rangubhet et al., 2017).

Eutrophication and water use

Intensive ruminant production systems generate large quantities of waste, which is a major environmental (soil, water and air) pollutant. Excess nutrients such as nitrogen and phosphorus, voided in faeces and urine, pollute waterways and underground water sources. In waterways, this leads to eutrophication, characterized by excessive plant and algal growth. A fairly new discipline that has evolved out of the desire by animal producers to reduce the excretion of nutrients into the environment is called econutrition, precision nutrition or environmental nutrition. This approach involves the formulation of cost-effective diets that meet the minimum nutrient requirements for acceptable performance, reproduction and carcass quality. The benefit is that there is minimal excretion of nutrients into the environment. Precision diet formulation strategies include the use of highly digestible proteins, synthetic essential AAs and use of phytase enzymes to enhance bioavailability of phosphorus and other minerals (Vasconcelos et al., 2007). However, this is not a major problem in animals that are reared extensively, and thus most ruminant production systems in developing countries cannot be faulted for this kind of environmental pollution. For the animal farmer, the interest in reducing nutrient concentration in waste is not only fuelled by environmental concerns but also by the desire to reduce feeding costs through optimizing nutrient assimilation into animal products for human consumption.

The determination of the water footprint of ruminants is a recent phenomenon prompted by consumer concerns about the depletion of water resources globally (Legesse et al., 2017). The increasing human population and associated rising demand for animal products means that demand for water to produce these products will also continue to rise (Doreau et al., 2012). The contemporary question is whether ruminant production contributes to water shortages globally. The short answer is in the affirmative, which is also true for any other enterprise where water is used. It is, however, also true that when water use is calculated per kilogram of product, animal products require more water to produce than crop products (Hoekstra and Chapagain, 2007). It is, therefore, critical that we ask whether water use efficiency in ruminants can be improved to avoid unnecessary wastage of this valuable natural resource. In ruminant production, water is used for feed production, drinking and during slaughtering and product processing. There are a number of strategies that can be used to improve efficiency of water use in ruminant production systems. These include selection of breeds that are adapted to dry conditions, use of crop by-products as feed, genetic improvement of forage plants for drought tolerance and adopting pasture irrigation techniques that improve water use efficiency (Doreau et al., 2012).

Ruminant products and human health

The health benefits of meat

Carbohydrates, proteins and lipids are the three major nutrients required by humans and meat supplies two of them: proteins and lipids. Meat protein is also considered to be of high biological value for human nutrition (Mlambo and Mapiye, 2015). This is because when defining protein quality (the extent to which the protein will meet the AA requirement of humans and, therefore, promote optimal function), it is the 'completeness' of their AA profiles that is used as a criterion. This completeness refers to the extent to which the essential AAs profile of the dietary protein matches the essential AA requirement of humans for a designated function, for example, growth, reproduction and work (Gehring, 2017). Ruminant products such as meat and milk are known to have high digestibility (95%) and provide all nine essential AAs (histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan and valine) required by humans (Gehring, 2017) in the right proportions. This is the reason why protein from ruminant products has higher biological value compared to plant protein. Apart from the macronutrients, meat is also a source of critical micronutrients that are necessary for healthy growth and development of children (Mlambo and Mapiye, 2015). For certain micronutrients such as vitamin B12, meat may be the only natural dietary source thus individuals that solely rely on plant food sources would need to take vitamin B12 supplements (Vargas-Bello-Pérez and Larraín, 2016). A number of micronutrients are better supplied via meat due to greater bioavailability than in other food or synthetic sources. Examples include iron (haem iron) and 25-hydroxycholecalciferol, a vitamin D precursor.

Lipids are a concentrated source of energy for humans, a structural component of the cell membranes, a source of essential fatty acids as well as a facilitator of metabolism of fat-soluble vitamins (Mapiye et al., 2015). There is wide variation in the proportion of unsaturated, monounsaturated and polyunsaturated fatty acids (PUFAs) in meat lipids. All three types of fatty acids can be found in meat, but the saturated and some trans-fatty acids have been considered to be the most undesirable as far as human health is concerned. This is despite recent evidence that ruminant meat contains small quantities of bioactive lipids such as C18:1t11 and C18:2 c9, t11, with known positive effects on human health (Vargas-Bello-Pérez and Larraín, 2016). Due to the biohydrogenation process that occurs in the rumen, ruminant products are predominant sources of saturated fatty acids as well as small amounts of trans-fatty acids (Mapiye et al., 2015).

Meat consumption and human disease: A smoking gun or a smokescreen?

The increasing popularity of vegetarianism in Western populations (Smil, 2002) is a reflection of the concerns regarding the role that meat (particularly red meat) plays in the aetiology of chronic diseases such as colorectal cancer, coronary heart disease and type II diabetes (De Smet and Vossen, 2016). It is, however, important to state that the exact aetiology of these diseases remains largely unknown despite years of scientific research (De Smet and Vossen, 2016). However, meat producers need to act on these concerns because the future role of meat in our society is changing in response to economic, environmental, ethical and health concerns. However, it is also important to note that an individual's risk of developing cardiovascular disease, diabetes or cancer is influenced by a variety of factors ranging from age, gender, genetics, alcohol intake, exercise, body weight, blood pressure, diet and many more (Willett, 2006). Given that humans rarely use meat as sole food items, it remains incredibly difficult to establish a cause–effect relationship between meat consumption and the incidence of these chronic diseases. Epidemiological studies indicate a positive association between diet and both cardiovascular disease and cancer even though this relationship is poorly understood (Willett, 2006).

Cardiovascular diseases and cancer are leading causes of death in many industrialized countries (Abete et al., 2014), thus it is of great concern for meat producers and consumers that meat consumption has been linked to incidence of these health problems. This is despite the fact that a comprehensive number of studies have revealed that, at current consumption levels, ruminant trans fats have no detrimental effects on key cardiovascular risk markers (Gayet-Boyer et al., 2014; Huth, 2007). However, it is true that ruminant meat has high levels of saturated fats and those ruminants reared in feedlots tend to have higher levels of total fat due to higher planes of nutrition. Given that saturated fatty acids impact on blood cholesterol levels, it is expected that excessive consumption of meat may lead to cardiovascular disease. Indeed, saturated fatty acids have been demonstrated to increase platelet counts and with them, the propensity of blood to clot while PUFAs have been shown to have the opposite effect (Gehring, 2017). However, it is also important to cite Huth (2007) and Mapiye et al. (2015) who report no links between trans fats (rumenic and vaccenic acids) in ruminant food products and cardiovascular disease. In other studies, conjugated linoleic acid (CLA) found in milk and dairy products has been shown to have anticancer activity (Gehring, 2017). Other research findings suggest that lean beef consumption does not increase the risk of cardiovascular disease (Stanner, 2005). Given the multiple factors that influence an individual's risk of developing cardiovascular disease, multiple strategies are required (not just reducing consumption of meat) to reduce this risk. These include increased physical activity, limited alcohol consumption, maintaining a healthy body weight and controlling blood pressure (Darden et al., 2013).

Another area of controversy is the relationship between meat consumption and cancer, one of the chronic conditions whose specific aetiology is also largely unknown. However, there is a general agreement that the relationship between diet and cancer is significant enough. For instance, the International Agency for Research on Cancer (IARC) has classified processed meat as 'carcinogenic' and red meat as 'probably carcinogenic' and recommended that the consumption of red meat should not exceed 100 g per day while that of processed meat should be below 50 g per day (IARC, 2015). Iron-haeme and nitrogen organic compounds formed in intestines from nitrates and nitrites as well as polycyclic aromatic compounds formed during the cooking of red meat are suspected to be the chief culprits in meat carcinogenicity (Pulina et al., 2016). However, a recent meta-analysis (Oostindjer et al., 2014) reports an inconsistent relationship between consumption of red meat and cancer. Similarly, the European Prospective Investigation into Cancer and Nutrition (EPIC) found no significant correlation between meat consumption and mortality from colorectal cancer in a large group (448,568 men and women) of Europeans (Rohrmann et al., 2013). In fact, the IARC study declares that no definitive evidence of the putative role of red meat as a carcinogen in humans was obtained from *in vitro* and *in vivo* studies.

Whatever the scientific consensus, or lack of it, on the effects of meat consumption on human health, it is clear that reflections on many fronts are required. For animal scientists and meat producers, this is an opportunity to identify and evaluate strategies that could be used to make meat and meat products healthier.

Designer animal products for human health?

Modifying physico-chemical properties of animal products through dietary manipulation is a possible way of resolving some of the health challenges discussed above (Shingfield et al., 2013). However, there are a lot more success stories using this approach in non-ruminants than in ruminants (Cheeke, 2004). The presence of microbes in the rumen means that dietary modification of the final product is more challenging because the microbes tend to modify dietary ingredients before their absorption and assimilation. For example, it is easy to increase the PUFA content of meat from simple non-ruminants by simply feeding them a diet containing higher levels of PUFAs. The same outcome cannot be achieved in ruminants without protecting the dietary PUFAs from microbial modifications, which include biohydrogenation that produces the offending saturated and trans-fatty acids (Shingfield et al., 2013). However, ruminants that are reared extensively tend to produce products that are much more desirable than those reared intensively (Van Elswyk and McNeill, 2014). The desirability of these products is based on consumers preferring products that are healthy as well as those that are organically and ethically produced (Webb and Erasmus, 2013). However, there is evidence of lower consumer preferences for dark-coloured grass-fed and higher preferences for light-coloured grain-fed beef (Duckett et al., 2013). Grass-fed beef also tends to be less tender compared to grain-fed beef since animals on pasture are reared at sub-optimal planes of nutrition thus attain market weight at an advanced age producing meat with greater amounts of connective tissue (Webb and Erasmus, 2013). The positives for grass-fed beef include that it is an organic product from animals that are reared in their natural environment, afforded space and time to exhibit all their natural behaviours, consuming plant biomass and has lower total fat and higher PUFA content than grain-fed beef (Van Elswyk and McNeill, 2014). Grass-fed meat products also tend to have higher CLA and omega-3 fatty acids on a g/g fat basis as well as higher antioxidant contents (Van Elswyk and McNeill, 2014). As a result, there is increased interest in grass-fed beef despite concerns regarding relatively longer production time, cost of production, seasonality of forage resources, greater enteric CH_4 emissions and less acceptable yellowish colour due to elevated carotenoid content (precursor to vitamin A) (Bjorklund et al., 2014).

Another cause for concern regarding the consumption of animal products is the presence of potentially harmful residues of feed additives. These include antibiotics, hormones and other chemotherapeutic agents used by producers to enhance animal performance and reduce production costs (Jeong et al., 2010). In most countries, the use of feed additives is regulated in order to protect the consumer. The banning of antibiotic growth promoters has created a gap, which researchers have been happy to address (Lillehoj et al., 2018). Research on alternative feed additives focusing on phytochemicals and probiotics has unearthed low-cost and effective alternatives to chemotherapeutic agents and antibiotics (Rangubhet et al., 2017). There is evidence that nutraceutical plants can replace the offending feed additives (Lillehoj et al., 2018). The adoption of these alternatives should contribute to the production of residue-free, safe ruminant products that are acceptable by consumers.

Animal rights and welfare – Implications for food security

Animal rights activists subscribe to the school of thought that says animals have rights and are not ours to use for food, clothing, entertainment or experimentation. Indeed, Rollin (1981) argues that non-human animals have a moral right to life – a position that makes it hard for animal producers to justify the use of animals as a source of food. However, animal welfare allows the use of animals as long as 'humane' guidelines are followed. Animal welfare relates to the ability of an animal to cope with its environment. For producers, meeting animal welfare requirements is important for regulatory, economic and ethical reasons.

Nearly all animal scientists agree that as long as we farm animals, we should guarantee that their physical and mental needs are catered for, that they are allowed space and time to perform their normal natural behaviours and that they are spared unnecessary suffering (Thorslund et al., 2016). This position is also necessitated by the fact that optimally reared animals tend to be more productive and produce products of better quality for the consumer (Maraba et al., 2018). Thus, animal producers' interest in the welfare of animals is based on both ethical and economic considerations, given that stress and disease are known to negatively affect productivity (Maraba et al., 2018). In addition, consumers of animal products may be prepared to pay more for products from animals reared in conditions that maximize their welfare. However, welfare-optimizing extensive rearing systems may not be as efficient as intensive production systems where feed conversion to meat products tends to be higher. With a rapidly increasing human population, the challenge is that demand for animal products is unlikely to be met by welfare-optimizing production systems but by intensive production systems, which offer suboptimal rearing conditions. Products from welfare-optimizing systems may be of good quality but could be priced beyond the reach of the resource-poor households (Maraba et al., 2018). To compound matters, extensive production systems for ruminants are also the biggest culprits when it comes to enteric CH_4 emissions due to the relatively low quality of feed and longer lifespans of the animals. In contrast, the much-criticized intensive production systems (based on animal welfare, use of human-edible feedstuffs and use of antibiotics and hormones) tend to be more environmentally friendly as far as enteric CH_4 emissions are concerned. For instance, while intensive farming receives a great deal of criticism for its cruelty and the overuse of antibiotics, it can be remarkably efficient to the benefit of the environment and food and nutrition security. Thus, welfare-friendly extensive ruminant production systems compromise environmental stewardship through higher enteric CH_4 emissions, while environmentally friendly intensive production systems compromise animal welfare, use antibiotic growth promoters and other chemotherapeutic agents and utilize food-grade grains. Clearly, there are pros and cons for each production system that require balanced analysis.

Optimal welfare standards are enforced by law or through market incentives (Thorslund et al., 2016). Ensuring minimum standards of animal welfare, such as optimal space allowance, non-restrictive housing systems and environmental enrichment, requires greater capital and time investment (Webster, 2005). As a result, it is important to establish a positive association between optimal welfare, productivity and desirable quality of animal products. This could motivate animal producers to meet or even exceed the minimum welfare standards. Unfortunately, very few empirical studies have investigated the relationship between long-term social stress and parameters such as growth performance, stress biomarkers and meat quality. In their seminal study designed to fill this gap, Maraba et al. (2018) concluded that 'unhappy' sheep (reared in solitary confinement) had lower oxidative status making them more susceptible to diseases. However, these researchers failed to demonstrate a relationship between housing stress and meat quality traits in Dohne Merino sheep suggesting that suboptimal welfare is not associated with quality of meat products in this ruminant.

Confronting the challenges

Ruminant products can be a critical source of protein of high biological value, natural trans-fatty acids (rumenic and vaccenic acids) with potential health benefits and bioavailable micronutrients for humans (Mapiye et al., 2015). However, the same products are associated with incidences of obesity and other chronic diseases. Similarly, ruminant waste products can provide valuable nutrients for crops and pastures while at the same time being responsible for environmental pollution. Improving the environmental performance of ruminants as well as establishing safe levels of consumption of animal products is critical to ensure the sustainability of the global food system (Herrero et al., 2013). Strategies include use of improved pastures, use of non-conventional feed resources, precision feeding, changes in land-use practices, selecting appropriate breeds of ruminants to curb the GHG emissions and water usage and production of 'designer' animal products with better appeal to the consumer in terms of health benefits and animal ethics.

Metabolically, the human body has low capacity to deal with abundance but is designed to effectively cope with scarcity (Birch, 1992). When this metabolic handicap is combined with a sedentary lifestyle, the outcome is that some of the lifestyle diseases currently afflicting humankind can be conveniently linked to meat consumption. As the adage goes, 'everything in moderation'; so should humans approach their use of ruminant food products. It is a biological necessity that milk and eggs be extremely rich sources of essential nutrients – after all, these products are designed to support exponential growth in young animals. Given that the growth rate of humans, even as children, is nowhere near that of chicks and calves, it must be obvious that we do not need to consume large quantities of these products, as we would end up with more nutrients than required – leading to some of the health problems associated with consumption of animal products.

Conclusions

There are numerous strategies and technologies with the potential to deliver efficient, environmentally friendly and consumer-conscious ruminant production systems based on high standards of animal welfare. Adopting these sustainable ruminant production practices will ensure that consumers of ruminant products approach the dinner table without any trepidation. In addition, these practices will minimize environmental costs of feeding the ever-growing world human population with ruminant food products and ensure sustainable ruminant production for food and nutrition security, environmental stewardship and thin waistlines.

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