NUTRITION-PARASITE INTERACTION- A REVIEW

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ABSTRACT

There are number of internal and external factors that affect the production performance of animals, among which parasites and parasitism are major of concern constraints to animal’s productivity especially in tropical countries. The usual mode of control of these gastro-intestinal parasites (GIP) by based on the repeated use of anthelmintics is now strongly questioned because of the increasing development of resistance to these molecules. Among the alternative methods to anthelmintics currently available, the manipulation of host nutrition in order to improve the host resistance and/or resilience to parasitic infections seems to represent one of the most promising options to reduce the dependence on conventional chemotherapy and to favor the sustainable control of GIP. This paper will discuss the interactions between nutrition and parasitism and will also refer to quantitative (influence of protein, energy, micronutrients and other phyto-additives) as well as to qualitative (organic livestock farming, foraging) aspects of the diet. The beneficial effect of nutrition, more specifically, the importance of protein nutrition for the maintenance of host immunity to parasitism, the potential use of novel crops and possibilities for biological control have also been discussed. Biological control of parasitic nematodes seems to hold promise for the future, but to be able to assist producers; the optimal delivery system needs to be refined and further developed. In addition, more work will be needed to define anthelmintic resistance, non-chemical alternatives to parasite control, modulation of immunity to parasites by genetic and nutritional factor, integrated parasite control strategy and the best use of these technologies in different geographic regions. Internal parasites are a potentially serious threat to the health, welfare and productivity of organically managed livestock, the ultimate goal of which is to eliminate dependence on antiparasitic drugs, however this is rarely achieved in practice. It is now realized that chemical anthelmintic treatment, on its own, may not provide a long term strategy for managing parasite in grazing ruminants. There is a growing awareness for strategic nutritional supplementation with far reaching consequences, viz. increased production of meat, milk and wool, and also of its quality, growth and reproductive efficiency, parasite control, enhancement of immunity and disease resistance.

Key words: Nutrition, Parasite, Animal health.

Feed intake and nutrient requirements have been recognized for long time as an important parameter for determining the efficiency of animal production. There are a numbers of internal and external factors that affect the production performance of animals, of which parasites and parasitism are major constraints to animal productivity throughout the world especially in tropical countries. Most of the parasitic infection in domestic animals is caused by gastro-intestinal (GI) nematode, which may result in depression in appetite, impairment in GI functions, alteration in protein, energy and mineral metabolism and changes in water balance. The major effects on host nutrition and health are, 1) irritation by biting flies, which modify grazing behavior and affect feed intake, 2) loss of nutrients due to sucking of blood, and 3) injection of toxins that affect metabolism. Nutrition can affect the ability of the host to cope with the consequences of parasitism and to contain and eventually to overcome parasitism. Since it is proposed that the host gives priority to the reversal of the pathophysiological consequences of parasitism over other body functions, it is to be expected that improved nutrition will always lead to improved resilience. On the other hand, it is proposed
that the function of growth, pregnancy and lactation are prioritized over the expression of immunity. Improved nutrition may affect the degree of expression of immunity during these phases and can thus influence the resilience and resistance of host to parasite infection. The interaction between the host and nutrition can be broadly discussed from two interrelated perspectives, i) the effects of nutrition on the metabolic disturbances and pathophysiology induced by parasitism and ii) the influence of nutrient availability on the ability of the host to mount effective response against parasite establishment and/or development and to induce parasite rejection.

Host-parasite interactions

Host-parasite interactions are often seen as an open competition, with parasites attempting to overcome host resistance to infection. Herbivory is a common route of transmission of parasites that represents the most pervasive challenge to mammalian growth and reproduction. Many parasites have complex life cycles, i.e. they have to pass through several host species to reach maturity. Hence complex life cycles often consist of invertebrate and vertebrate hosts; the parasite likely varies in the machinery required for infection, exploitation and transmission of each host. The first difficulty for a parasite in a complex life cycle, compared to a single host system, is to successfully manage the additional transmission steps between hosts. Orally transmitted parasites often depend on predation of the current host by the next host. Therefore, to enhance transmission probability, parasites would profit from increased conspicuousness of the current host, at the time when the parasite is ready for transmission to the next host. After a parasite successfully found and orally entered the next host, an important step is the penetration of the intestinal mucosal wall. In each host, parasites have to survive the encounter with the host’s immune system. If parasites with complex life cycles cope better with one of the different types of host immune systems, the parasite should perform differently in the other hosts. This substantiates the constraint of both hosts’ immune systems on parasite performance and the impact on evolution of virulence in a parasite with a complex life cycle (Hammerschmidt and Kurtz, 2005). There are great variations in life cycle, intermediary hosts, reproductive forms, and pathogenesis, which are responsible for differences in interaction between the host and the parasite, and the nature of the response of the host (Solomons and Keusch, 1981).

a) Harmful effects of the parasite on the host

Many parasites are harmful effects to their host, but in most cases these effects are not of such importance that the host is being killed. Such effects comprise:

i) Wasting (cachexia, spoliatrices): African trypanosomiasis and leishmaniasis may lead to severe loss of weight in both animals and man.

ii) Superinfections: In the case of (muco)cutaneous leishmaniasis ulcerations may lead to superinfections with bacteria

iii) Production of toxic compounds: It is thought that the African trypanosome, when in the central nervous system, produces aromatic amino-acid analogues that may influence brain function.

iv) Immunodepression: Malaria, bilharziosis, etc., lead to a certain degree of immune suppression which renders the infected host more susceptible to other diseases.

v) Allergic reactions: In the case of onchocerciasis (river blindness) the presence of the filarial worms under the skin may lead to depigmentation due to allergic reactions.

vi) Anaphylactic shock may be induced by the sudden release of large amounts of parasite internal antigens into the bloodstream.

vii) Also drug treatment leading to a massive killing of the parasites may result in anaphylactic shock.

viii) Irritative reflexes (intestinal contractions: ascaris)

ix) Irritation of skin and tissues by ecto- and endoparasites

b) Beneficial effect of parasite to host

Besides the harmful effects of parasite to host, many parasites are beneficial for host by different ways. First, it has been shown that parasites can have a role in structuring host communities. They can have differential effects on the different hosts that they exploit, they can directly debilitate a host that it is a key structuring force in the community, or they can indirectly alter the phenotype of their host
Effect of parasitism on host

c) Nutrient utilization

Gastro-intestinal parasitism affects the nutrient utilization of host in many ways, viz. i) reduce nutrient availability to the host through reduction in voluntary feed intake (VFI) and/ or reduction in the efficiency of absorbed nutrients; ii) increased loss of endogenous protein into the GI tract (Holmes, 1993), partly as a result of leakage of plasma protein, and partly due to increased mucoprotein production and sloughing of epithelial cells in to the alimentary tract; iii) effect on GI motility causing diarrhea enhances the loss of plasma protein, sodium and chloride with increase in potassium level thereby altering acid-base balance; iv) an increase in metabolic protein/amino acids requirement as a consequence to endogenous protein loss (MacRae, 1993); and v) diversion of nutrients and protein synthesis from production processes such as muscle, bone, wool, milk, egg, etc. towards repairment/replenishment of local tissue injury at GI level, mucus secretion and/ or loss of plasma or blood and other defensive and immunomodulatory system during parasitism.

d) Energy metabolism

The major metabolic consequence of parasitism, especially of the blood-borne parasites is an increase in energy (maintenance) requirements due to increase in heat increment as a result of fever (Verstegen et al., 1991). A 15% rise in metabolic rate (Blaxter, 1989) and 25% rise in maintenance requirement (Verstegen, 1991) for every degree rise in body temperature have been reported. Klassing (1991) points out that whole body utilization of glucose increases by 68% during the acute phase response to infection. Reductions in the digestion of the gross energy of the complete diet have been frequently reported in a range of helminthes infections in both cattle and sheep (e.g. Sykes and Coop, 1977; Verstegen et al. 1991; Perkins et al. 1990). Sykes and Coop (1977) found the gross efficiency of utilization of ME for growth was reduced by 30 and 37 % for O. Circumcincta and T. colubriiformis infections respectively. Increased heat production may be expected to accompany the increases in protein turnover, but there appear to be no reports of such increases. A detailed investigation of the partitioning of dietary energy in subclinical haemonchosis using direct calorimetry (Stevenson, 1989) showed fecal and urinary energy losses not to be significantly reduced by infection with 350 H. contortus /kg live weight, nor was there any effect on heat production. However, infected animals lost a greater proportion of dietary energy as methane. Energy retention and the efficiency of utilization of ME for gain purposes were not significantly different. Unfortunately the establishment of the infection was particularly low in this study. Level of feed intake affects heat production and where the gross efficiency of energy utilization was apparently impaired in infected animals this was largely because of reduced intake. However, net efficiency of utilization of ME for production (i.e. feed ME less maintenance cost) is related to the energy density of the complete diet, and in the calorimetry findings reviewed (Kloosterman and Henken, 1987) derived maintenance and net efficiency values were extremely varied and generally not related to infection. Findings from carcass evaluation (e.g. Sykes and Coop, 1977; Coop et al. 1983; Stevenson, 1989) however, show infected animals to have lower energy retention. There is clearly a shortage of information and understanding of energy metabolism in parasitized ruminants.

e) Protein and amino acid metabolism

Many balance studies have demonstrated that reduced N retention is often a characteristic
feature of gastrointestinal parasitism. This very often results from increased urinary N loss, implying a reduction in the efficiency of utilization of absorbed amino acids. The radio isotopic techniques referred to earlier have shown that high levels of blood protein loss into the gastrointestinal tract are a consistent finding in helminth infections, but the increases in fecal N, as reported by Sykes and Coop (1977) and Symons et al. (1981 a), may represent only a relatively small proportion of the total endogenous protein loss which has escaped absorption. Poppi et al. (1981), using cannulated sheep infected with *T. colubrijormis*, demonstrated no differences in the true digestibility of 35S-labelled bacteria in the small intestine or apparently digested N over the whole tract. However, there were plasma protein losses into the small intestine with an increased ileal N outflow and urinary N excretion. Stevenson (1989), commenting on these observations, regarded the deduction that a large part of the extra ileal N was cell sloughing and mucin secretions as unlikely in view of its relative indigestibility. Indeed Rowe et al. (1982) showed that blood loss accounted for nearly all the additional abomasal N outflow which was seemingly reabsorbed before the terminal ileum. Roseby (1977), working with *T. colubrijormis* infection, has shown increases in the caecum-proximal colon volatile fatty acid and ammonia concentrations and pool sizes and speculated that increased microbial fermentation occurred. Microbial deamination of amino acids would result in an increase in ammonia absorption at the expense of amino acid uptake. Protein digestion is initiated in the abomasums and completed in the proximal small intestine, liberated amino acids being mainly absorbed from the mid-third of the small intestine (Steel and Symons, 1982). *O. osterragi* infection is thought to bring about pH-mediated limitation on abomasal protein digestion, but in a monospecific infection this is nullified by a compensatory increase in digestion in the small intestine. In a combined *O. ostertagi* and *C. oncophora* infection study (Parkins et al. 1990), the colonization of the small intestine by *C. oncophora* and associated mucosal damage may well have prevented any compensatory response and, thereby, the reported crude protein digestibility reduction. In addition the greatly increased plasma loss would have contributed to the increased fecal N loss. Some degradation of the extra N entering the gastrointestinal tract to produce ammonia may have been responsible for increased urinary N loss in infected calves.

**f) Mineral and vitamin metabolism**

Subclinical parasitism influences bone metabolism through changes in phosphorus and calcium absorption, leading to reduced bone growth (van Houtert and Sykes 1996). Other changes in micronutrients occur as part of the suite of changes associated with sub-clinical infections, including decreases in copper uptake and changes in sulfate metabolism (Sykes 1987). There may be release of Cu and resorption and sequestration of Fe and Zn in protein-calorie malnutrition (PEM), infection and acute starvation. In addition to vitamin A deficiency Co deficiency may also enhance the susceptibility to disease (also decreases Vit-B₁₂ synthesis). However, the role of micronutrients in for-age selection is relatively undescribed but worthy of investigation.

**Nutritional strategy to control parasitism**

**a) Enhancing feed and nutrient intake**

Adequate plane of nutrition is one of very basic aspect which modulates the nutritional status and health of the animals. The animals gradually recover with the gradual increase in feed intake and body weight. The animals ultimately become apparently normal due to their normal immunocompetence mechanism. Therefore, there should be selection of feed ingredients that are palatable or supplementation of appetite enhancer (molasses, micronutrients, processed feed ingredients, flavours, colours etc.) to restore VFI in parasitized animals and also provision of concentrated nutrients (energy and protein) in the feed consumed by the animals to meet the minimum maintenance need during a disease process.

**b) Nutritional enhancement of immunity to parasitism**

Modulating immunity of the animal to the infection by nutritional manipulation is one of the latest modus operandi in control and prevention of parasitism disease. Acquired immunity in the host has effects on parasite establishment, development, survival and fecundity (Quinnell and Keymer, 1990). The duration of the phase of acquisition of immunity, during which the immune system recognizes the parasite and the changes that precede an effective
immunological response could vary greatly from a few days in protozoan infection to several weeks in helminth infection. Nutrition of the host could have the potential to affect how rapidly immunity is acquired and expressed in defense of the parasitism. Under normal nutritional circumstances, changes in nutrient intake would not be expected to affect the early rate of acquisition of immunity to parasites in young animals (Coop et al., 1995). However, in severely undernourished animals that lose protein mass, the acquisition of immunity is severely impaired. There is a large inter-animal variation in the rate of development of resistance both within the same breed and between breeds which appear to have a strong genetic basis. Host protein and energy nutrition can affect greatly, the expression of immunity in cattle (Mausour et al., 1992), sheep (Coop et al., 1995). Van Houtert et al. (1995) observed that supplementation of a hay diet with 150 g protected protein or 100 g fish meal per day affected the rate of worm expulsion after 10 weeks of trickle infection with T. colubriformis and the apparent rate of expulsion was related to the level of supplementation. As many component of the effector arm of the immune system such as immunoglobulins, mucoproteins and cellular products (leukotrienes) are all proteinaceous moieties, they would be expected to draw on protein resources both in quantitative and qualitative terms (Yu et al., 1999). Immune system has also some specific requirements for certain micronutrients such as Zn, Fe, Se (Chandra, 1993).

c) Supplementing micronutrients
Supplementation of minerals and vitamins can play a key role in affecting ruminant susceptibility. Studies on the relationship of phosphorous (P) with T. vitrinus worm burden in sheep suggest that increased P supply decreases mean worm burden (Coop and Field, 1983). Trace elements like Cu, Mo, and Se are known to influence the host resistance to nematode infection with a probable direct anthelmintic effect and by influencing host metabolism (Coop and Kyriazakis, 1999). They found reduced worm burden (H. contortus, O. circumcincta) in lambs by administering copper oxide wire particles (CWOP) in the diet. Treatment with CWOP appears to have the potential to reduce establishment and worm fecundity of Haemonchus spp for an extended period and may offer livestock producers a supplementary means of reducing larval contamination of pasture particularly in areas where anthelmintic resistance is a problem and copper supplementation is likely to be beneficial (Knox, 2002). Two gram of COWP was effective in alleviating H. contortus infection and reducing number of egg-laying nematodes in the abomasum with the lowest concentration of copper in the liver (Burke et al., 2004). Further, Burke and Miller (2006) observed that multiple doses of COWP were as effective as levamisole for control of H. contortus without risk of copper toxicity. Martínez Ortiz de Montellano et al. (2007) observed reduced worm burden of of H. contortus and T. colubriformis in browsing goats supplemented with copper oxide needles (Copinox, 2 g capsules). In caecal coccidiosis (E. tenella), an increased levels of selenium and vitamin E found to reduce the severity of primary infection and improve weight gain and feed conversion (Nockels, 1991). Vitamins A, D, and B complex are integral in developing immunity to parasites. Essential minerals include cobalt, used to synthesize vitamin B12, and iron. It is also observed that when the phosphorus level of the diet was at a level of 0.28% phosphorus on a dry matter basis, the weight gain of lambs infected with parasites was increased by 40% over those lambs fed a low (0.18%) phosphorus level diet.

d) Use of herbal feed additives
Herbs have been used for years by farmers and traditional healers to treat parasitism and improve performance of livestock, and many modern commercial medicines are derived from plants. However, scientific evidence on the anti-parasitic efficacy of most plant products is limited, regardless of their wide ethnoveterinary usage. The possible positive effects of plant secondary metabolites (PSM) as additives in the livestock rationing include antioxidant and anthelminthic properties and complex formation between protein and condensed tannins that protects dietary protein from degradation by the symbiotic microflora of foregut fermenters, increasing its utilisation by the animal. This protein effect is probably only beneficial to animals under a narrow range of nutrient-rich conditions found mainly in agricultural systems. In vivo controlled studies have shown that plant
remedies have in most instances resulted in reductions in the level of parasitism much lower than those observed with anthelmintic drugs. Although in many cases the active compounds in the herbal remedies have not been fully identified, plant enzymes, such as cysteine proteinases, or secondary metabolites, such as alkaloids, glycosides and tannins have shown dose-dependent anti-parasitic properties. However, as some of the active compounds may also have anti-nutritional effects, such as reduced food intake and performance, it is essential to validate the anti-parasitic effects of plant products in relation to their potential anti-nutritional and other side effects. Condensed tannins (CT) have shown biological effects that may aid in the control of dewormer-resistant internal parasites (IP) and thus CT in forages have potential to be a component of IP control programs (Athanasiadou et al. 2003; Hoste et al., 2005). Plant CT may have direct or indirect effects on IP. Direct effects might be mediated through CT-nematode interactions affecting physiological functioning of IP. Recently, in vitro and in vivo studies have shown that CT in several temperate and tropical forages (Hedysarum coronarium, Onobrychis viciifolia, Lotus pedunculatus, L. corniculatus, Lespedeza cuneata, Quercus, Accacia and Quebracho CT) can inhibit infective gut worm larvae of sheep and goats and both gut and lung worms in farmed deer, with effects influenced by both concentration and structure of CT. It is suggested that Calliandra could reduce faecal egg counts of lambs infected with T. colubriformis, and that such an effect is mediated probably by some direct toxic or physiological effect of the legume rather than by improvement in protein nutrition (Cresswell, 2004). Indirectly, CT can improve protein nutrition by binding to plant proteins in the rumen and preventing microbial degradation, thereby increasing amino acid flow to the duodenum. Several ovine studies have shown that improved protein nutrition reduces parasite infestation. This is assumed to be mediated by enhanced host immunity, which may be especially important with selection for immunity to IP.

Saponin mixtures present in plants and plant products like Fenugreek, Sesbania, Soapnut etc. possess diverse biological effects and it is observed to be detrimental to protozoa. This property could be exploited in treatment of protozoal infections in other animals. Triterpenoid and steroid saponins have been found to be detrimental to several infectious protozoans such as Plasmodium falciparum (Traore et al. 2000), Giardia trophozoites (McAllister et al. 2001) and Leishmania species (Plock et al. 2001). The toxicity of saponins to protozoans seems to be widespread and non-specific and is obviously the result of their detergent effect on the cell membranes.

A mixture of essential oils from clove (1.0%), thyme (0.1%), peppermint (0.1%) and lemon (0.1%) observed to have effects on coccidia oocyte output and the number of Clostridium perfringens in broiler chicks when artificially inoculated (Evans et al., 2001).

A lot of other bioactive components, viz. terpenes, triterpenoids, alkaloids, etc. has variable effects as antimicrobial agents. The possible anti-parasitic role of these compounds cannot be ruled out. It has also been said that there may be a synergistic effect of two or more components against intestinal parasitism.

Other methods to control parasitism

Biological control

This can be achieved by application of sound management practices; breed and strain selection; preventive husbandry; optimal nutrition and appropriate stocking densities. Grazing management thus provides a mechanism by which parasite challenge to individual animals can be reduced. Immunity to parasites is modulated by genetic and nutritional factors as well as by exposure. Novel forage crops such as Lotus or chicory are being evaluated for their parasite control properties. An integrated parasite control strategy combines grazing management, nutritional and breed aspects with strategic dosing where necessary (Wells, 1999). Thus, biological control may include incorporation in the diet of forage crops containing condensed tannins as a means of countering parasite-induced production losses and dinginess (Sahoo et al., 2004). Some common botanical dewormers include garlic (pills, powders, fresh, tinctures); wormwood (Artemisia spp.); wild ginger or snakeroot; goosefoot; conifers (pine, spruce, or fir); mustard; squash or pumpkin seeds; carrot and fennel seeds; pyrethrum...
A plant extract from *Chrysanthemum* and several others. Despite having use of alternative parasiticides, organic farmers rely on fine-tuning their nutrition regimes, herd and pasture management, as well as field and soil practices so they can learn to coexist with parasites.

**Competitive inhibition**

*Duddingtonia flagrans*, a net-trapping, nematode-destroying fungus, appears to be the most promising candidate. This fungus, producing sticky three-dimensional network and now isolated worldwide, is special due to its capacity to prolifically produce high numbers of thick-walled resting spores, chlamydospores, which survive passage through the gastro-intestinal tract of grazing livestock and are capable of growing and subsequently trap nematodes, including larval stages of parasitic nematodes. The great potential of this fungus as a biological control agent has been demonstrated through numerous trials with cattle, sheep, horses, and pigs. Although the potential use of *D. flagrans* chlamydospores has been verified through numerous trials it is necessary to develop practical delivery systems such as slow release devices, feed-blocks or similar to be able to implement this tool in future integrated control strategies. The introduction of microfungi for biological control could be as part of a feed supplement or incorporated in feed-blocks presented to animals which are raised under relatively intensive conditions and constant surveillance. Since the first Conference on Novel Approaches to the Control of Helminth Parasites of Livestock in Armidale, Australia, 1995, there has been a steady evolution within the area of biological control of parasitic nematodes.

**CONCLUSION**

The growing interest in host nutrition-parasite interaction per se imply the improving host resilience and/or resistance to infection through management practices by manipulation of nutrients and above all the nutritional health of the host. The implication of changes in host resistance with nutritional state for host productivity need to be better described. Understanding the role of nutrition in improving both resistance and resilience of the host to GI parasites will be important if producers are to make better use of host acquired immunity and reduce dependence on pesticides for prophylaxis. Therefore, future strategies should be aimed at i) systematic studies to establish regulatory mechanism through which the therapeutic diets intended at improved host nutrition keeping in view the Nutrition-parasitism interrelationship, ii) the role of amino acids, vitamins and micro-nutrients in relation to host resilience/resistance, iii) drug-nutrient interaction for improved therapeutic efficiency, iv) exploration of plant bioactive components against parasitism, and v) innovative foraging and pasture management strategies to reduce worm burden.

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