Soluble non–starch polysaccharides affect net utilisation of energy by chickens

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Summary

Feed constituents such as the non–starch polysaccharides (NSPs) not only affect nutrient digestion in general, but also influence gut dynamics through changing the types and numbers of the microflora and the secretory response of the gut. The use of nutrients such as starch through microbial fermentation is not energy efficient; increased endogenous secretion of water, protein, lipids and minerals can affect post–digestive and, perhaps, post–absorptive processes because the gut secretes some 20 hormones or regulatory peptides. This paper discusses the importance of evaluating feed constituents from the standpoint of 'efficiency' and presents some experimental data on the effect of soluble NSPs on the net energy value and losses of energy as heat and as volatile fatty acids in the excreta of broiler chickens.

Introduction

The measures used to assess the nutritive value of poultry diets to date are metabolisable energy and amino acid contents, which also are the bases for practical diet formulations. The use of a net energy system for energy and digestible amino acid values for diet formulations has been strongly advocated in recent years (Farrell 1996; Ravindran *et al.* 1998; Ravindran and Bryden 1999). The rationale is that the efficiency of energy utilisation and the digestibility of amino acids are affected by diet constituents and that it is logical to consider the amounts of nutrients 'available' to the animal when evaluating feed. However, gut dynamics in relation to absorption of nutrients and their regulation and energetic costs have been given little attention in nutritional research. Considering the fact that 20% of whole animal energy expenditures can be accounted for by the gut (McBride and Kelly 1990; Cant *et al.* 1996), it is essential to investigate the way feed constituents behave in the gut and their effect on energetic efficiency of feed utilisation.

One constituent that has negative effect on the nutritive value of grains in poultry is the content of soluble non–starch polysaccharides (NSPs) (Burnett 1966; Antoniu *et al.* 1981; Annison 1991). This paper discusses how soluble NSPs affect energy utilisation beyond digestive processes in poultry.

Effect of NSPs on post–digestive processes

The effect of soluble NSPs on the apparent digestibility of nutrients in poultry has been studied extensively during the past ten years (Bedford *et al.* 1991; Choct and Annison 1992a). The negative correlation between NSPs in the diet and its nutritive value has been demonstrated in poultry (Choct and Annison 1990; Annison 1991), in pigs (King and Taverner 1975) and in dogs and cats (Earle *et al*. 1998). A general inhibition of the digestibility of nutrients occurs when diets with high levels of soluble NSPs are fed to chickens. Thus, Choct and Annison (1992a) demonstrated that addition of a soluble NSP isolate from wheat to a broiler diet depressed the ileal digestibilities of starch, protein and lipid by 14.6, 18.7 and 25.8%, respectively.

It is believed that viscous gut contents impede nutrient digestion by reducing the mixing of digestive enzymes with their substrates, but the effect of NSPs on the gut is not limited to their physical characteristics. They can induce changes to the microflora of the gut and modify endogenous secretion. These effects of NSPs on nutrient digestion are inter–related and depend on the solubility, molecular weights, and solution configurations of the polymers. Solubility of NSPs, in turn, depends on their chemical structures and association with other cell wall components.

The role of viscosity in the anti–nutritive effect of NSPs has been demonstrated by numerous workers (Bedford *et al.* 1991; Bedford and Classen 1992; Choct and Annison 1992b; Dusel *et al.* 1998; Steenfeldt *et al.* 1998). Choct and Annison (1992b) depolymerised an isolate of wheat arabinoxylan (MW 758,000 Daltons) using a xylanase *in vitro* so that its viscosity was reduced four–fold. When these depolymerised NSPs were included in broiler diets, they did not exhibit strong anti–nutritive effects on nutrient digestion compared with intact NSPs included at the same level. NSPs can also bind nutrients and form complexes with digestive enzymes and some regulatory proteins in the gut. Angkanaporn *et al*. (1994) showed that addition of soluble arabinoxylans to a broiler diet markedly increased endogenous losses of amino acids, leading to a significant decrease in the apparent digestibility of protein in the ileum. The gut secretes some 20 hormones or regulatory peptides (Unväs–Moberg 1992), some enhance nutrient absorption, and others depress it. Feed components that have effects on endogenous protein secretion can be supposed to have an effect on hormonal secretions. Furthermore, viscous NSPs can enhance bile acid secretion and subsequently result in significant loss of these acids in the faeces (Ide *et al.* 1989; Ikegami *et al.* 1990). In addition to the modification of the gut physiology, certain NSPs can also bind bile salts, lipids and cholesterol (Vahouny *et al.* 1980; Vahouny *et al.* 1981). The net effect may be an altered lipid metabolism in the intestine, resulting in increased hepatic synthesis of bile acids from cholesterol to re–establish the composite pool of these metabolites in the enterohepatic circulation. The continued ‘drain’ of bile acids and lipids by sequestration, and increased elimination as faecal acidic and neutral sterols, may ultimately influence the absorption of lipids and cholesterol in the intestine. These effects could lead to major changes in the digestive and absorptive dynamics of the gut, with consequent poor overall efficiency in nutrient assimilation by the animal.

NSPs on energy losses via heat increment and as volatile substances in excreta

The energy derived from microbial fermentation in the chicken is small in quantity and inefficient as a metabolic fuel (Bolton and Dewar 1965). NSPs can bring about significant changes to the ecology of the gut, e.g. proliferation of fermentative microbes in the small intestine which ferment digestible nutrients such as starch to VFA (Choct *et al*. 1996). The amount of these VFA absorbed from the gut is not known. It is thought that the effect of soluble NSPs on the net utilisation of energy of feedstuffs for poultry may be more pronounced than that on the apparent metabolisable energy (AME) value because: (1) the digestive system of the bird would have to work harder than usual to cope with a highly viscous gut environment, and (2) the proliferation of fermentative organisms in the small intestine of chickens is energy–inefficient and detrimental to the bird. In a recent study using a close–circuit calorimetric system, we (Tukei, Thomson and Choct, unpublished data) examined the effect of NSPs on energy utilisation in broiler chickens. In the first experiment, the loss of energy as VFA in the excreta of birds fed maize and barley was compared because these ingredients represent the two extremes amongst cereals in terms of their soluble NSP levels. As shown in Table 1, there was a large difference between birds fed maize and barley in the energy loss as VFA in the excreta, apparently indicating that elevated levels of soluble NSPs affected the way nutrients were digested. To test this finding further, we determined the net energy (NE) value of an NSP–enriched diet with or without enzyme supplementation in a second experiment. As the level of NSPs increased in the diet, the energy losses as heat increased and a considerable amount of energy was lost as VFA in the excreta. Thus when the anti–nutritive properties of the NSPs were removed by use of an exogenous enzyme, the AME and NE were increased by 29.1% and 37.3%, and heat production and energy loss as VFA were decreased by 11% and 61%, respectively. The data are shown in Table 2.

The increases in AME and NE were not proportional, indicating that NSPs not only interfere with digestive processes, but also have strong negative effects on net utilisation of energy. Part of this discrepancy may be explained by the loss of energy as VFA in the excreta. The use of nutrients through microbial conversion of digestible carbohydrates, such as starch, to VFA is not efficient compared to a direct absorption of glucose released from enzymatic digestion (Müller *et al.* 1989; Furuse and Okumura 1989; Carré *et al*. 1995). The production of VFA is energetically costly due to their costs of production and the energy losses as VFA in the excreta.

It is apparent that nutritionists should start to pay more attention to post–digestive and post–absorptive processes when evaluating nutritive quality. These include gut microbial balance, changes in gut dynamics such as secretory regulations and re–partitioning of nutrients. Muramatsu and colleagues (Muramatsu *et al.* 1983; 1987; 1993) clearly demonstrated that gut microflora increase energy costs by modifying the rate of energy–consuming reactions such as protein turnover within the chicken body. One such example is the gut cell turnover. According to LeBond and Walker (1956), a 100 g rat gaining 5 g/d synthesises 1 g mucosal cells daily, which represents a 20% additional tissue synthesis not manifest as weight gain. Extrapolating this to a 2 kg bird gaining 60 g daily, the bird would synthesise 12 g of mucosal tissue to maintain the integrity of its small intestine. Increased microbial load can exacerbate this loss (Abrams *et al.* 1963; Lesher *et al.* 1964) since some of its fermentation products, e.g. putrescine, have been shown to significantly enhance small intestinal and colonic mucosal growth rates (Osborne and Seidel 1989; Seidel *et al.* 1985). The indirect evidence of such costs is the often significant improvement in bird performance resulting from the inclusion of antibiotics in high–NSP diets (MacAuliffe

Table 1 Apparent metabolisable energy (AME) and loss of energy as VFA in the excreta of broilers fed maize or barley.

	Maize	Barley
AME (MJ/kg dry matter)	16.5	13.4
Excreta VFA energy (kJ/bird/day)	11.4	31.6
Excreta VFA energy (kJ/kg DM intake/bird)	159	433

Table 2 AME, net energy and loss of energy as VFA in the excreta of broilers fed a NSP enriched wheat based diet with or without enzymes.

	Wheat + NSPs (– enzyme)	Wheat + NSPs (+ enzyme)
AME (MJ/kg DM)	10.5	14.8
Respiratory quotient	0.995	1.006
Heat production (MJ/kg liveweight/day)	0.91	0.81
Net energy (MJ/kg DM)	4.7	7.5
Excreta VFA energy (kJ/bird/day)	56	17
Excreta VFA energy (kJ/kg DM intake/bird)	371	145

and McGinnis 1971; Misir and Marquardt 1978a,b). Supplementation with 150 mg procaine penicillin per kg of a diet consisting of 82% rye and 13.4% casein, resulted in increases of 75% in weight gain, 37% in feed intake and 37% in feed efficiency. However, there were no significant improvements in the AME (11.43 vs. 11.06 MJ/kg DM) and the digestibilities of starch (95% vs. 96%) and protein (40% vs. 40%) (Choct 1991). A better bird health and a more efficient nutrient utilisation are the likely reasons for this improvement.

Manipulation of efficiency of nutrient utilisation for poultry

In the light of a situation where fewer, if any, antibiotics may be allowed in feeds during the next decade, the use of antibiotic growth promotants is not a long term option for improving the efficiency of nutrient utilisation in the livestock industry. As shown in Table 2, the inclusion of appropriate glycanases in diets containing high levels of soluble NSPs can reduce energy losses as heat and as VFAs in the excreta, thus leading to improved net energy value. The reason for this action is speculative. Perhaps reducing the viscosity of the digesta in the small intestine hastens digesta passage and nutrient digestion rate (through removal of the diffusional constraint of viscous gums), thereby providing less substrate for the fermentative organisms and less time for them to proliferate. This may in turn promote the normal and efficient digestion (enzymatically) of starch and protein in the small intestine. Use of other exogenous agents to manipulate gut dynamics and post–digestive and post–absorptive processes should be examined in a systematic manner for future feed and livestock production.

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