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Use of Urea Treated Crop Residue in Ruminant Feed

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ABSTRACT

Large amounts of crop residues are produced annually globally which are hitherto rendered waste. Various farm wastes i.e. crop residue have been effectively, efficiently and economically employed in form of all-inclusive diets. This study summarizes the importance of this waste to ruminant animals especially in developing nations where there is major feeding requirements constraint mostly during the dry seasons of the year. The all-inclusiveness of these residues are created by treating and fortifying these wastes with technologies highlighted in this review. The development and improvement of the quality of this fibrous crop residue is the main thrust of this study through nutrient balancing and amend major nutritional flaws inherent in them. Few practical ways were mentioned and described, others ways to harvest more gains from crop residues were highlighted.

Keywords: Dry seasons, Treatment, Crop residue, Crop improvement.

1. INTRODUCTION

Small ruminant's production has been given a pride of place in animal production in Nigeria in view of its multipurpose roles. It contributes immensely to animal protein supply in Nigeria. Lebbie (2004) reported that goats and sheep occupy a unique responsibility in the food chain and overall livelihoods of rural households. Their contributions to national livelihood include income generation, store of wealth, and security during periods of lack etc. The production of these animals constitutes substantially to animal agriculture which complements agricultural economic activities of food processing and brewing industries and makes use of agricultural by-products as feed materials. They can be reared for various reasons such as income generation, religious purposes, household consumption, hobby and as security against crop failure (Ozung *et al*., 2011). The manure generated by sheep and goat are veritable source of organic manure for crop production. They are well recognized as an integral part of subsistence farming and contribute substantially to the rural economy. Sheep and goats are a very prominent feature of the subsistence rural economy in most West African homes, even in places where cattle are not commonly kept (Tweneboah, 2000).

Sheep and goat are widely spread in the dry areas of the world and therefore, the population increases all over the world. Consequently, flock sizes are larger in drier than in the humid areas. Thus, in some areas (e.g. West Africa) flock sizes decreases from north to south (ILCA, 1979; Otchere *et al*., 1985). Sheep and goats are a major part of livestock production in Ghana which accounts for 7% of the Agricultural Gross Domestic Product (Oppong-Anane, 2001). According to FAOSTAT (2008), sheep numbers were in excess of one billion (1,078,200,000) and goat numbers (861,900,000) were steadily approaching that number. This is in spite of inherent factors that mitigate against the commercial production these small ruminants In spite of the general neglect of both research and commercialization of their production, statistics show that the annual increase in sheep and goat population in most West African countries averages 18-20% and 10-20% respectively (Tweneboah, 2000).

Nutrition has been universally recognized as the major constraints to small ruminant productivity in Nigeria and Sub-Saharan Africa. Their major sources of feed are the natural grasses and legumes which depend on seasonal water supply from rainfall. They are abundantly available during the rainy season and become scarce during the dry season especially in northern part of Nigeria. The main feed resources for small ruminants are natural pastures consisting of legumes and browse species (Mubi, 2003).

These pastures depend on rainfall, which fluctuates especially in the northern part of the country where the largest percentage of the animals is raised. This has severe impact of their productivity because there is shortage of energy and protein feedstuffs. The increase in human population and resultant human activities that results in competition for available land that could have been grazing have worsen the challenges of small ruminant feeding. These activities include agricultural and non-agricultural further worsens the situation because of the pressure placed on the available land for grazing. Aruwayo and Maigandi (2013) reported that the nutritional problems of ruminants have been increased by competition between man and the animals for the scarce grains and the protein concentrates feed making it difficult to meet up with nutritional requirements of the animals at affordable cost. Another challenge is the poor nutritional content of the pastures during the dry season. Steinbach (1997) reported that during this period, the available forages are dry, protein content is very low and there is marked decrease in voluntary intake and digestibility by the animal. Other factors which have contributed to the increasing cost of feed are under-production of various ingredients used in feed formulation and high inflation rates. Low quality feeding materials like roughages have been readily available alternative during periods of scarcity. These include crop residues obtained immediately after harvest. Otchere (1985) reported that crop residues support small stocks feeding when they are let loose fend themselves after harvest. Improved animal nutrition appears to be a more critical factor in increasing small stock productivity. Grasslands in the tropics constitutes the cheapest source of nutrients for ruminants but cannot supply these nutrients all through the year hence the need for supplementation with agro industrial bye-products and crop residues for optimum productivity (Van Vlaenderen 1985 and Kolff and Wilson (1985) and improved growth rate. The crop residues include maize stover, rice straw, sorghum straw, millet straw etc. other residues of importance include cocoa husks, corn, brewery by-products etc. However, these crop residues and agro industrial by-product have not been optimally utilized for ruminant's feeding [Adeyanju *et al*., (1975), Otchere *et al*., (1983)].

2. CROP RESIDUES AS LIVESTOCK FEED

Ruminants are known for its ability to utilize materials and roughages that of little value to non-ruminats as a result poor nutritive values. This is due the presence of microorganism in their rumen that are able to degrade fibrous materials. Crop residues constitute are obtained from the farm and are parts of plants after harvest and processing of the primary crops. Notable among the crop residues are maize stover, cowpea haulms, cassava tops and peels, cob of maize and are usually fibrous, low in nitrogen and form the basal or principal feed in small-scale farming systems during the dry season (Smith, 1988). The residue of guinea corn, millet, soybeans, rice straw has been of tremendous help in alleviating the challenges of shortage of feed. Residues from Fibrous crop and farm are mostly classified into cereals, grain from legumes, roots and tubers etc. (World Bank, 1989; Nordblom and Shomo, 1995). These by-products from agriculture originate from mixed crop-livestock systems (Thornton *et al*., 2002). El-Nouby (1991) explained that these by-products are those materials obtained other than the main product for which the crop is cultivated. They include on-farm by-products or crop residues (leaves, straws, stubbles, tops etc.) (El-Nouby, 1991) and agro-Industrial by-products (AIBP) which are obtained from crop processing: banana peels, cassava peels, cocoyam peels, cowpea husk, plantain peels, rice bran, rice husk, maize husk and yam peels (El-Nouby, 1991).

FAO (1999) reported that over 1000 million tonnes of cereal residues are obtained every year in the developing countries. If used strategically, a country like Ghana could save up to 186 million kg of livestock weight that is lost during the 120-day dry season from its 2.3 million tonnes of cereal crop residues produced (Amaning-Kwarteng, 1991).

Large quantities of crop residues are used as animal feed in many countries, but much is still wasted for various reasons or used for other purposes (Tesfaye, 2006). With regard to the use of crop residues for animal feeding, Kossila (1985) reported that in both developed and developing countries, crop residues account for about 24% of the total feed energy suitable for ruminant livestock. The author further stated that if all crop residues were considered, the total production would on average give 3.4 tons and 6166 Mcal metabolizable energy (ME) per year in the whole world. Sandford (1989) study revealed that in different areas of semiarid sub-Saharan Africa countries, residues from cropping supply as much as 45% of the feed consumed by ruminants every year and 80% in periods of extreme feed shortage. Thole *et al*. (1988) conducted a study in India with sorghum stover contributing 20 to 45% feed consumed by dairy animals reared on small scale.

Although crop residues are known to have such a significant contribution to the livestock feed requirements, there are varying opportunities for their use as animal feeds (Thole *et al*., 1988). The greatest potential for the use of Farm residues capacity to improve animal feed's challenge is optimized in system when crop and livestock are mixed. (Kossila, 1985). Where crop and livestock production are segregated, most crop residues are wasted or they are used for non-feed purposes (Kossila, 1985). It was discovered that the remains of cropping is able to meet up with the feed requirements in beef (Klopenstein *et al*., 1987) and dairy (Klopenstein and Owen, 1981) productions especially during favourable situations.

Timothy *et al*. (1997) stated that crop remnant use for ruminant feed depends on the extent of population, animal management, transportation and market facilities. In locations with lower population and communal feeding of animals, they observed that open

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access to residues do occur as opposed to where there is large population of humans and livestock respectively in which restricted access to residues is practiced. Anderson (1978) reported that utilization of crop remnants depends of locations.

Moreover, as residues must be collected and transported for efficient utilization, the financial capacity of the farmers to undertake such activities also becomes a major factor regulating their extent of utilization. The dependence on remains for livestock feeding surges as farmstead sizes decreases. In summary, the use of crop residues for animal feeding not only improves animal production but it also increases the overall utilization efficiency of crops such as maize whose utilization efficiency is low (Tesfaye, 2006). In this regard, Alemu *et al*. (1991) stated that when only the grain is used for human consumption or for livestock feed, only about 39% of the energy and 20% of the protein are utilized.

Ruminants animals fed on residues from crop, by-products and arable weeds add value to resources which are largely wasted in the absence of a ruminant component in the system (Jutzi, 1993). Kossila (1985) reported that the use of globally available crop residues for ruminant feeding would have supplied improved dry matter and nutrient intake but for the low level of use which could be due to associated challenges. These include difficulty in collection, transporting, storage and processing, alternative uses, seasonality and low nutritive value. (Sansoucy and Emery, 1982; Owen, 1985). Their digestibility is low and are poor in mineral and vitamins (Owen, 1993). This was supported by (Greenhalgh, 1984; Kabaija and Little, 1988) that residues of farm operations like rice straw is low in nutrients that essential for the wellbeing of the animals like sulphur, phosphorus, cobalt and vitamins A and E. They are high in cell wall content and possess digestibility (<50 %) and poor unintentional consumption of as low (10-20 g/kg liveweight) (Nicholson, 1984; Doyle *et al*., 1986). Minerals that are found to be deficient in tropical grasses are also lacking in these crop remains. Examples are sodium, copper and phosphorus, sulphur, cobalt and calcium. Little (1985) reported that crop residue based feeds could lack sodium, copper and phosphorus. Calcium and magnesium are wasted as oxalates and silicates in urine and feaces due to high amount oxalis and silicates some of the farm remains. The loss of these nutrients was reported by Owen (1993) to be part of the reasons for the poor palatability of crop residues and then consequent poor intake. Devandra, (1991), Preston (1995) and Tingshuang *et al., (*2002) supported other reports that residues from farm and crop are low in metabolizabled energy and crude protein. The variation in availability and quality of feed due to seasonal changes constitutes a serious problem for production sheep, goat, cattle and other roughage dependent livestock. This was also reported by (Onwuka and Davies, 1996). Among the ruminants, goats have been considered to be more efficient in the digestion of crude fibre and the utilization of poor roughages than sheep (Malechek and Provenza, 1983; Squires, 1984; Gihad *et al*., 1980). Possible physiological and behavioural factors for this ability of the goat have been indicated (Louca *et al*., 1982). However, with medium and good quality forage and adequate feed availability goats apparently are similar to sheep in nutrition (Malechek and Provenza, 1983; Huston, 1978).

3. CONSTRAINTS OF USE CROP RESIDUE

There are obvious limitations to feeding animals with farm residues which made it beneficial itb to be treated for improvement of the nutritional value. Although their nutritive value and digestibility is very low, crop residues are especially suitable for ruminant livestock feeding and provide small ruminants with most of their annual nutritive intake (Gatenby, 1985). Crop residues are invariably bulky, high in fibre, poorly degraded in the rumen, low in nitrogen and minerals resulting in very low intakes (Osuji *et al*., 1995). The low digestibility results in limited intakes of these untreated residues usually characterized by low nitrogen content, high cell wall components and little cell contents. Peterson *et al*., 1981 reported that animals fed on crop residues perform poorly due to low intake, poor nitrogen content and low digestibility but Saenger *et al*.,(1982) study revealed that treatment of materials with chemicals improves the solubility of hemicelluloses fractions and consequently improving the intake dry matter of dry matter and digestibility. The cell walls, which constitute the major fraction of crop residues may be highly indigestible, depending on the relative proportions of its component parts; lignin, cellulose, hemicellulose, silica, and how they are complexed with each other (Smith, 1988). When such residues are fed, structural polysaccharides (which comprise the carbohydrate fraction) are only partially degraded by the rumen microorganisms. This results in low digestibility and low rates of disappearance or passage from the gastrointestinal tract during digestion and limited intake, thus limiting the value of crop residues as a feed component (Adebowale, 1988).

Crop residues as feed resources need to be improved during the dry season, especially in Sub-Saharan Africa. It has been established that intake and utilization of crop residues, especially the high lingo-cellulose cell-wall materials may be increased by various pre-treatment methods which improve the rumen environment for growth of cellulolytic microbes, thus, facilitating a greater rate of fibre digestion [Jackson (1977); Sundstol *et al*. (1979); Gatenby, (1985); Adebowale (1988); Orskov, (1990)]. Mehrez and Orskov (1977) reported that species, variety, environment, methods of harvesting and handling, feeding methods which include diet composition, levels of feeding and efficiency of treatment affect digestibility of crop residues. From ruminant dietary standpoint, plant material is made up of two components - cell contents and cell wall, these component contains polysaccharides which prevents easy of digestive enzymes (Meng, 1990; Morrison *et al*., 1989).

This portends great danger for these animals that depend on then especially during the dry season of the year when conventional feed stuff is scarce and in some cases almost not available. It then becomes imperative for the treatment of this farm remains to make them more acceptable and nutritive. According to Morrison and Brice (1984), palatability and digestibility of roughages are improved with treatment.

Some of the challenges associated with the use of crop residue as ruminant feed include:

1. Young shoot can grow again which is capable of causing prussic acid poisoning e.g. Sorghum and brassicas produce substances that block the uptake of iodine and when animals graze these crops or the residues for a long, uninterrupted period, iodine deficiency symptoms occur (e.g. abortions and death of young animals).
2. Some residues from plants and crops produce toxins like trypsin and solanin.
3. Again feeding these animals with waste from maize cobs, tubers and others may gag the animals' throats.

The use and adoption of residues from crops by many countries have been influence by several factors i.e. availability, capital investment, quality, labour costs, processing and price (William, 1989; Jayasuriya, 1993; Tingshuang *et al.*, 2002). It was however concluded that understanding the socio-economic factors limiting the utilization of crop residues and adoption of new feeding systems is the most fundamental principle in assessing the need for additional and alternative feeding systems or improving on the existing feeds and feeding systems for improved adoption and utilization by farmers (Tsopito, 2003). Lack of adequate information on availability, improvement and utilization of crop residues and agro-industrial by-products use as ruminant feed is one those challenges militating their use.

Devandra (1991), Preston (1999), Tingshuang *et al.*(2002) and Kossila (1985) stated that if all the potentially available crop residues could be utilized for feeding, each herbivore would receive over 9kg DM and about 17 Mcal ME/day, thus largely covering requirements. Unfortunately, a much lower level of utilization is possible because of problems of collection, transportation, storage and processing, alternative uses, seasonal availability, and more importantly, their poor feeding value. Smith (1993) stated that most crop residues are deficient in protein, essential minerals like sodium, phosphorous and calcium, and are rather fibrous (40 to 45 % crude fiber). The consequences of such a profile for ruminants are a low intake (1.0 to 1.25kg DM/100kg live weight), poor digestibility of the order of 30 to 45%, and a low level of performance. Low intakes and poor digestibility result specifically from high cell wall lignin content and the chemical bonding between this fraction and the potentially nutritious cell wall constituents such as cellulose and hemicelluloses. Limitations associated with feeding straws to ruminants include: the slow rate and low total digestibility, low propionate fermentation pattern in the rumen, and the negligible content of both fermentable nitrogen and by-pass protein. The mineral content of straws is generally low and imbalanced but deficiencies are unlikely to be manifested in animals at maintenance. For production of meat and milk, requirements for minerals are increased many folds and supplements should be supplied.

Other issues that are considered critical in crop residue utilization include deterioration that set in as temperature increases towards the end of year. Rapid physiological maturation which results in early lignification with the protein and phosphorus contents falling to very low levels while the fiber content increases (Becker and Lohrmann, 1992; McDonald *et al*., 1995; Nyamangara and Ndlovu, 1995). Lignified roughages become increasingly resistant to mechanical and microbial degradation in the rumen. The resistance of lignified roughages was reported to responsible for the long retention time of tropical roughages in the rumen. Long retention time facilitates rumen fill and consequently decreases feed intake (Thorton and Minson, 1973; Aitchison *et al*., 1986).

4. UREA TREATMENT IN IMPROVEMENT OF CROP RESIDUE

In view of the obvious challenges associated with use of farm residues as feed for ruminants, it is imperative that the treatment has led to improvement in their nutrient value The use of urea to treat crop residue is very simple. Researchers have worked on various ways of improving the feeding values. These include Chemical, Physical, Physico-chemical, Biological, Generous offer (ad libitum feeding) and Supplementation. However, urea treatment has variously used, hence the attention on it this review. Chemical treatment has been used to improve the feeding value of crop residues (Waller, 1976).The upgrading of cereal straws by means of ammoniation with gaseous or liquid ammonia has received considerable attention in many temperate countries (Sundstol *et al* 1978). An alternative method of ammoniation, using urea as the source of ammonia, has been reported by several research workers (Saadullah *et al* 1981; Kritzinger and Frank 1981; Hadjipanayiotou 1982a; Cloete and Kritzinger 1984). Many of the factors influencing the effectiveness of straw treatment with urea (Sundstol *et al* 1979; Hadjipanayiotou 1989; Cloete and Kritzinger 1984) like type and level of chemical, reaction period, ambient temperature, quantity of water (moisture level) and physical form (Kay 1972), are closely related to the economics of straw treatment (Hadjipanayiotou 1989). It involves dissolving it in water and then spraying in on the residue on ensiling. Chenost and Kayouli (1997) described the process of urea treatment as a simple technique consisting of spraying a solution of urea onto the dry mass of forage and covering with materials locally available so as to form a hermetic seal. The process involves the hydrolysis of urea into gaseous ammonia and carbonic gas through reaction with an enzyme called urease which is produced by ureolytic bacteria within the forage being treated. The

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ammonia thus generated provokes the alkaline reaction which gradually spreads and treats the forage mass. Kayouli (1996) reported that in Niger, stovers and straws were treated with 5% urea (5kg urea dissolved in 50 liters of water to treat 100kg dry residue) and made into a stack using the traditional storage method and locally available air-tight system: silos made from Andropogon gayanus or briquettes made from clay and straw. Air-tightness was successfully ensured by tying with braids made from Andropogon gayanus and no plastic sheets were required.

In urea treatment, the ammonia generated from urea by bacterial and/or plant ureases in the ensiling process hydrolyses the chemical/physical bonds between lignin and the cellulose and hemicelluloses in the plant cell wall. The hydrolysis of these bonds makes the cellulose and hemicelluloses more accessible to microorganisms in the rumen and increases total fermentation and usually the rate of fermentation. Some chemical hydrolysis of hemicelluloses also takes place resulting in an increase in the portion of soluble carbohydrates in the straw (FAO, 1986). Response to urea treatment is thus a combination of the effect of the alkali on cell wall structure and the effect of added nitrogen on rumen microbial activity (Preston and Leng, 1984). Chenost and Kayouli (1997) stated that the success in urea treatment depends on interdependent factors such as the presence of urease, the rate of urea applied, the moisture content, the ambient temperature, length of the treatment period, the degree of the hermetic sealing achieved during treatment and the quality of forage to be treated.

From the report of Chenost and Kayouli (1997) regarding urea application rate, it is now well established that the optimum rates lie between 4 and 6kg urea per 100 kg of straw matter which corresponds to treating with ammonia in a range of 2.27 to 3.4 kg (one molecule of urea, (60g) generates two molecules of ammonia, that is 34g). 4 to 5kg urea per 100 kg of dry straw is in use in countries like Thailand, China and Sri Lanka while in others, 6 to 7 kg per 100 kg dry straws are used (Chenost and Kayouli, 1997). Bui and Le (2001) however reported that DM, crude fiber (CF) and organic matter (OM) degradability of rice straw treated with 4 or 5% urea were slightly higher than that of the straw treated with 2.25 % urea plus 0.5 % lime. According to Nguyen *et al*. (1998), 3 % urea and 0.5 % calcium hydroxide may be better economically than 5% urea rice straw treatment. Said and Wanyoike (1987) recommended 5% urea treatment for maize (batches of 10kg chopped stover sprinkled with urea solution made of 0.5kg urea dissolved in 10 liters of water) in a period two weeks in Kenya.

5.EFFECTS OF UREA TREATMENT ON CHEMICAL COMPOSITION OF CROP RESIDUES

According to the Chenost and Kayouli (1997), the effects of ammonia generated during urea treatment are: dissolving the parietal carbohydrate mainly the hemicelluloses, swelling the vegetal mater in an aqueous environment, so easing access by the rumen cellulolytic microorganisms, easing mastication by the animals and digestion by the microorganisms by reducing the physical strength of cells and enriching the forage in nitrogen content. The net effect of the treatment process is increased nutritive value through increasing forage digestibility by as much as 8 to 10 points, nitrogen content by more than double and intake by as much as 25 to 50%. Butterworth and Mosi (1985) reported that sheep did not show any response when urea treated haricot bean and horse bean haulms was fed to sheep. This was attributed to the higher level of lignin in the forages. However, other authors found out that 4% urea treatment significantly improved the digestibility of the straw which was reported to have been due to reduction ADF and NDF contents of the forage. Investigation carried out by Wongsrikeao and Wanapat (1985) on buffaloes using urea treated rice straw showed 92.8% dry matter and 3.8% crude protein for untreated straw while 60.8 % dry matter and 6.8% crude protein was obtained for 6% urea-treated straw. It was also discovered in the same study that dry matter digestibility of ureatreated straw was higher (55.4%) than that of the untreated straw (43.2%). The result of research conducted by Chairatanayuth and Wannamolee (1987) with sorghum head residue with urea or urea in combination with water melon seeds revealed that urea can be used to improve the nutrient content of residues.

Other authors like Tran and Nguyen (2000) conducted a research that impact of urea treatment on the chemical composition of four levels of urea (1.5, 2, 2.5 and 3 %, w/w) used in treating maize stover for 4 different periods (1, 30, 60 and 90 days). It was discovered that the Z the CP components of urea treated maize stover increased while the CF decreased as level of urea increased. Brand *et al*. (1991) also came out with the report that nitrogen content of ammoniated (with 55g urea/kg straw) wheat straw increased markedly. This went further that ammoniation generally lowers the NDF and hemicelluloses contents of crop residues.

An experiment was conducted by Shen *et al*. (1998) had an outcome that untreated and urea treated rice straw differed straw degradation. Their finding showed that urea treatment significantly increased straw DM and OM degradability with an average DM and OM degradability of the straw increasing by 18 and 24.5 %, respectively after 96-hour incubation. The report of Flachowsky *e*

t al., (1996) showed that stover treated efficiency of utilization of the ammonia nitrogen would be greater with compared with stover supplemented with urea because of the higher DM degradability and hence the more energy obtained from the urea treated stover diet. Flachowsky *et al.* (1996) stated that the nitrogen incorporated during treatment is readily available for use by rumen microbes as confirmed by the high rumen ammonia levels on urea treated stover.

5. EFFECT OF UREA ON VOLUNTARY FEED INTAKE OF CROP RESIDUE

The quality of any roughage depends on the voluntary intake of that roughage and on the extent to which its dry matter (DM) can supply dietary energy, protein, minerals and vitamins when eaten by the animal (Kossila, 1985). Many factors influence the intake of roughages among which are feed characteristics, animal species, physiological state and management practices (Khanal *et al.*, 1999). Most straws contain about 70-80% cell wall constituents, which represent an energy source for ruminants. Voluntary feed intake (VFI) is the amount of food eaten by an animal during a given period of time when an excess of the food is available (Sundstol and Coxworth, 1984). Food intake is important in defining food conversion efficiency (FCE). Efficient food conversion, however, will be achieved only if an animal is able to obtain from the food a substantial margin of nutrients above maintenance requirements. In many animal production systems, maximum intake may not be sufficient to ensure maximum production, or may be critical to the system (Jewell and Campling, 1986).

Treatment of roughages with either urea or ammonia is an effort to increase intake (Castrillo *et al*., 1995; Flachowsky *et al*., 1996) through alkaline hydrolysis of lignocelluloses bonds (Sundstol and Owen, 1984) and to increase nitrogen concentration in the roughage. This would allow an even release of ammonia in the rumen, creating favourable conditions for intense microbial fermentation. Voluntary feed intake has been found to increase when treated roughage is made available to ruminants (Jewell and Campling, 1986; Silva *et al*., 1989; Brand *et al*., 1991). Aitchison *et al*. (1988) offered urea treated and urea supplemented straw (i.e. straw sprayed with urea before feeding) to mature sheep and found a 21 % increase in dry matter (DM) intake for animals fed urea treated straw. Increased roughage intake due to urea treatment has been reported (Joy *et al*., 1992; Brown and Adjei, 1995; Schiere and de Wit, 1995). Similarly, Fahmy and Orskov (1984) reported that the OM intake of ammonia treated barley straw was 73% higher than for the untreated straw and the intake of digestible organic matter was improved by 98 %.

A linear increase in intake of cereal straws has also been observed with urea treatment up to 7 % (Macdearmid *et al*., 1988) and 8% (Jayasuriya and Perera, 1982) of the roughage OM.The digestible organic matter intake of rice straw was also increased by 0.42 and 0.27 kg day-1 due to urea and ammonia treatment, respectively compared with untreated straws. In an experiment, Manyuchi *et al*. (1992) reported that treatment of straw with ammonia or supplementing straw with 200 or 400 g of ammonia treated straw resulted in an 80, 56 and 59 % increase in intake, respectively. The report by Silva *et al*. (1989) showed an increase of OM intake from 414 to 729 g/day in sheep and from 4.75 to 6.09 kg day-1 in cattle due to ammoniation. Mira *et al*. (1983) observed that steers offered urea treated straw consumed 1.36 ± 0.236 kg day-1 more than those offered untreated straw. Hadjipanayiotou *et al*. (1997) reported higher values of voluntary intake of urea treated straw relative to untreated straw. Superiority of urea treatment as opposed to urea supplementation has also been reported for voluntary intake. Khanal *et al*. (1999) reported an increase of 17.4% in OM intake after animals were fed urea treated wheat straw. Experimental evidence (Cloete and Kritzinger, 1984) indicates that the voluntary intake of ammoniated wheat straw by sheep was increased by 8.1% and 46.7% over that of urea supplemented and non-supplemented straw, respectively. The beneficial effect of urea treatment in ruminant diets has been associated mainly with the increase in N for better utilization of roughages. Significant improvement in rumen environment (Silva and Orskov, 1988) and higher live weight gain (Castrillo *et al*., 1995; Flachowsky *et al*., 1996) were found after urea-treated barley straw diets were fed to ruminants. Hadjipanayiotou *et al*. (1997) identified a 12.4 % improvement in weight gain of crossbred heifers fed urea treated barley straw relative to urea-supplemented diet.

6. PERFORMANCE OF ANIMALS FED UREA TREATED CROP RESIDUES

In Niger, Kayouli (1996) observed that the consumption of urea-treated forages during dry season is often accompanied by an improvement in body condition of the animals and maintenance of live weight. The animals were also more resistant to diseases and their coat was improved (brighter hair). Thin and weak animals recuperated rapidly and milk from dairy cows increased significantly. Moreover, farmers have noted a positive effect on animal fattening in such a way that the fattening period was reduced with a consequent saving in concentrates. According to Preston and Leng (1986), the technique of using urea-treated forages also enables the use of animals with higher genetic merits as these animals can consume much of the digestible feeds to meet their requirements. Another positive effect of urea treated forages, observed by Kayouli (1996), is that feeding of such forages to draught oxen resulted in improved body condition with no loss of weight during ploughing period. Moreover, animals worked harder and longer (often ploughed 1.5 to 2 hours more per day) than those fed on untreated straws and stovers.

Urea treatment increases the acceptability and voluntary intake of the treated straw as compared with the untreated straw when it is fed ad libitum. The increase in intake is very important because what and how much animals eat (their feed intakes) are the most important factors that determine the productivity of ruminants (Kayouli, 1996). In this regard, Wongsrikeao and Wanapat (1985) found a significant difference in dry matter intake between the urea treated and untreated rice straw with values of 5.87 and 7.32 kg/day for untreated and treated straw, respectively. In terms of animal performance, those animals that fed the urea treated straw gained 0.21 kg/day while those that fed the untreated straw lost 0.13 kg/day.

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From feeding of 2.5 % urea treated maize stover as a sole source of roughage to growing cattle, Tran and Nguyen (2000) found that the treated straw had positive effects upon intake, digestibility and growth rates of the animals during a 60-days feeding trial. In a trial which compared the relative effectiveness of ammoniation using urea and supplementing untreated rice straw with a molasses-urea block (MUB), Bui and Le (2001) found consistently higher growth rates for crossbred cattle on ammoniated straw compared with those on the MUB supplemented untreated straw (449 vs. 363g per head per day). The improvement in growth rate due to urea treatment was 25% ($p<0.001$). The DM intake of the straw was also higher ($p<0.001$) for the group fed ammoniated straw than those fed the straw supplemented with MUB. Although moderate rates of live weight gain can be obtained with ruminants on diets based on treated crop residues, better animal performances require supplementation of such residues with nutrients that have beneficial effects on rumen function. Research works done in Thailand and Australia depicted that the critical supplementary nutrients on a straw based diet are bypass protein, starch and long chain fatty acids. High rates of growth were obtained when the ammoniated straw (urea ensiling in Thailand and ammonia gas in Australia) was supplemented with starch, protein and oil in the by-product meals that are known to escape rumen fermentation (Elliot *et al*., 1978a and 1978b). Live weight gain of young Brahman bulls weighing 150 kg increased from 0.47 to 0.83 kg/day as the level of supplementation of ammoniated rice straw with a mixture of fat, protein and rice starch increased from 1 to 3 kg/day (Wanapat *et al*., 1986). In another study on the effects of various levels of bypass protein supplementation on the body weight change of cattle given diet of ammonia treated or untreated rice straw, sole treated rice straw gave 52.1 % more growth rate than the untreated one. The live weight gain further increased to as high as 639 and 365 g/day due to protein meal supplement on treated and untreated straw, respectively (Preston and Leng, 1986).

By feeding urea treated wheat straw with limited amount of concentrate composed of cottonseed cake and wheat bran to Chinese cattle, Ma *et al*. (1990) found considerable improvement in 48 hours' degradability (69.4 and 47.3 % for treated and untreated straw, respectively). Moreover, the ammoniation resulted in faster and more efficient growth and was also cost effective. The percentage improvement obtained in daily weight gain, DM conversion and cost of feed per kg gain due to treatment were 341 % (485 vs. 110g), 76.4 % (10.8 vs. 44.3) and 64 % (1.82 vs. 5.0 Yuan), respectively. In another study by Gao (2000), Chinese Yellow cattle (young bulls) of 160 to 210 kg live weight and 12 to 14 months of age were fed wheat straw treated with anhydrous ammonia or urea plus 1.0, 1.5 and 2 kg/day of cotton seed cake. Though the live weight gains of animals given the anhydrous ammonia treated straw were significantly higher than that of the animals given urea treated straw, daily weight gains of 602, 687 and 733g were attained for urea treatment plus the 1.0, 1.5 and 2kg/day of supplement, respectively.

From their study with yearling crossbred (Friesian x Malawi Zebu) cattle, Munthali *et al*. (1992) reported the highest live weight gain for animals fed 4 % urea treated maize stover supplemented with 2 to 3 kg maize bran per day. The authors attributed the improvement in live weight gain to the increased intake of energy and an accompanying improvement in the utilization of non-protein nitrogen in the urea treated straw. Study at ILCA (1983) has also indicated that mature non-working oxen fattened readily on straw-based diets when given fermentable nitrogen such as urea and small amounts of oilseed cakes. Promma *et al*. (1985) studied the effects of urea treated rice straw on growth and milk production of crossbred Holstein Friesian dairy cattle. From the results they concluded that urea treated rice straw with concentrates, minerals and vitamins can be used instead of other Preserved feeds such as grass hay, silage or fresh grass as no differences were found in live Weight gain of the heifers.

7. CONCLUSION

Crop residues are and will continue to be a valuable feed resource for ruminant livestock production. Crop/livestock production systems and the socioeconomic conditions in which they operate will change. We need not only to take advantage of the opportunities within existing systems but also to prepare for new scenarios that will require us to rethink our management strategies and devise new technical tools to help us form and apply them. Treatments can be employed for improving the feeding value of low quality fibrous crop residues. The improved use of crop residues for animal feed involves cooperation from many disciplines in research and extension. Quite some work is already done and needs to be applied where possible.

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