Review

Wood ash in livestock nutrition: 2. Different uses of wood ash in animal nutrition

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Abstract

Wood ash is a mineral source that is readily available in most subsistence farming communities. The potential use of wood ash as a mineral source in animal nutrition is evaluated and reviewed. The predominant mineral in wood ash is calcium (Ca), and thus a potential Ca source in animal diets. However, the wide, source-dependent variations of Ca and other minerals in wood ash are limiting factors in the extensive use of ash in livestock diets. Ca sources with a less variable mineral composition such as feed lime ($CaCO_3$) and limestone are therefore preferable. This restricts the inclusion of wood ash in diets except where a good estimate of its Ca content is available. Specific situations exist under subsistence farming conditions in which wood ash could be used as a Ca supplement, for example when kitchen waste high in cereal products or cassava tuber meal that is low in Ca is fed to livestock. Variation in the concentrations of most trace elements in wood ash is even wider than that of Ca. However, it is suggested that trace elements in wood ash formed when combustion is at temperatures below 500 ºC have a relatively high bioavailability. Therefore, wood ash could be a valuable source of trace elements under subsistence farming conditions. Wood ash is an alkaline product which has been utilized in the alkaline treatment of roughages to improve digestibility and also to reduce the tannin content of feedstuffs. Contrary to other hazardous alkali such as NaOH used in the treatment of feedstuffs, wood ash is a non-corrosive alkali. It is suggested that these treatments would be feasible under resource-limited farming conditions. However, attention will have to be given to the problem that products containing ash would have a high Ca to P ratio which could result in a phosphorus deficiency in livestock.

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Abbreviations: Al: aluminium; Ca: calcium; Cu: copper; Fe: iron; K: potassium; Mn: manganese; Mg: magnesium; Mo: molybdenum, P: phosphorus; Se: selenium; Zn: zinc

Introduction

When plant material including wood is burnt, the inorganic residue left is ash, and ash is usually readily available in subsistence farming communities. Ash is considered a waste product, though it has the potential to be used in agriculture. Wood ash is a source of Ca (Van Ryssen & Ndlovu, 2018) which can be used in resource-limited farming situations.

Application of ash to soil appears to be a practical method of disposing of wood ash, because it helps to recycle nutrients back onto the soil (Campbell, 1990). In fact, wood ash has been found to be a good fertilizer, and can be used as a source of plant mineral nutrients when applied to forestry and agricultural soils (Naylor & Schmidt, 1986; Campbell, 1990; Olanders & Steernari, 1995). Österås (2004) noted that the restoring of nutrients to soil through fertilizing with wood ash is critical, especially in areas where trees are harvested commercially. Although ash has low fertilizing properties, it can be used as a substitute for lime and limestone to neutralize acidic soils through supplementing Ca, K, P, Mg, and replacing microelements that would have been depleted from the soil during plant growth and harvesting (Naylor & Schmidt, 1986). Liming with wood ash may reduce the toxic effects of Al and Mn on plants grown in acidic soils. An indirect benefit of using wood ash as a fertilizer would be the rise in the pH level of acidic soils that would increase the bioavailability of elements such as P, Mg, Mo, and Se in plants (Reid & Horvath, 1980), which in turn would be beneficial to animals consuming those plants.

The objective of this presentation is to review the use or potential use of wood ash in animal nutrition with special reference to minerals in the ash of subtropical tree species, as reported by Van Ryssen & Ndlovu (2018).

Wood ash as a dietary ingredient

Cereal grain-based balanced diets require the inclusion of Ca, especially in diets for laying hens (NRC, 1994). Wood ash as a Ca source has been included in such diets by replacing limestone (Van Ryssen *et al*., 2014). However, limestone is a relatively cheap source of Ca and is readily available. This limits the need for alternative sources of Ca. Therefore, the inclusion of wood ash in animal diets as a Ca source would be restricted to situations where large quantities of ash are readily available, and where it is economically justifiable to analyse the ash before it is included in the diet.

In subsistence farming systems animal performance is relatively low and wood ash can be used effectively as a Ca source for poultry (Ochetim, 1988). Van Ryssen *et al.* (2014) substituted feed lime with wood ash in a diet for slow-growing broilers and recorded no difference between the two sources of Ca in growth and leg characteristics of the birds. Similarly, Oso *et al*. (2011) reported that the performance of broilers were similar when comparing Ca sources such as oyster shell, snail shell, wood ash, and limestone. However, they recorded that chickens on a diet containing wood ash developed leg problems such as slipped tendon.

When formulating a complete diet in which ash is used, more ash than limestone must be included in order to supply the Ca required in a diet. To be sufficient in Ca and P, the diets formulated by Van Ryssen *et al*. (2014) contained 19 to 23 g limestone/kg and 26 to 33 g wood ash/kg, and those of Oso *et al*. (2011) 22.7 g limestone and 37.1 g wood ash/kg. Wood ash would dilute the concentration of other nutrients in the diet and therefore the concentration of, for instance, available energy. In both studies approximately 3% wood ash was included in the diets. These findings suggest that wood ash should not be included in diets intended for high-performing livestock.

In rural and subsistence farming communities, kitchen waste containing cereal grains is often available and fed to livestock. However, cereal grains and their by-products are deficient in Ca (Bredon *et al*., 1987). In such situations, wood ash would be an excellent Ca source. Cassava tuber is another feedstuff that is used widely in tropical regions worldwide, both in animal and human nutrition (Oke, 1978). One of the nutritional limitations of the cassava tuber is its very low Ca content (Oke, 1978). Chávez *et al*. (2005) analysed 600 different cassava genotypes and reported mean concentrations of 0.76 g Ca/kg and 1.65 g P/kg on a DM basis. Under these feeding situations wood ash would fit in well as a supplemental Ca source.

A practical problem that Van Ryssen *et al*. (2014) identified in their study was that fine wood ash tended to separate from other dietary ingredients, except when macadamia oil cake meal that contained relatively high levels of oil was included in the diet. Another characteristic of wood ash and wood bark ash is the variety of other mineral elements they contain, apart from Ca (Van Ryssen & Ndlovu, 2018). However, this is similar to many commercial sources of Ca such as limestone (Naylor & Schmidt, 1986; Van Ryssen, 1993) because the mineral composition of limestone depends on the composition of the rock mined. Van Ryssen (1993) recorded a limestone source containing 5000 mg Mn/kg compared to another source containing 45 mg Mn/kg. Mavromichalis (2015) indicated that dolomitic limestone contains more than 100 g Mg/kg, while it has also been documented that high levels of fluoride are often present in Ca and P sources (Suttle, 2010).

With the dominant presence of Ca in wood ash, it can be assumed that a large proportion of trace elements in wood ash would be present as carbonates and bicarbonates, considering the low temperatures of wood burning in homestead fires, as suggested by Van Ryssen & Ndlovu (2018). Although the relative value (RV) for carbonate salts is usually lower than reference salts, as quoted by Ammerman *et al*. (1995), it can be assumed that high levels of trace elements in wood ash would make a substantial contribution to the supply of trace elements to animals consuming diets containing wood ash. To what extent their bioavailability would be comparable to those of trace minerals in limestone is yet to be determined, although Ammerman *et al*. (1995) indicated that the bioavailability of Mg and Fe in dolomitic limestone is relatively low, and Suttle (2010) reported the low bioavailability of Fe sources such as oxides, hydroxides, and carbonates in soil originating from rock. It is proposed that the bioavailability of trace elements in wood ash would be relatively high compared to those in a product such as limestone.

A high bioavailability of minerals in wood ash can be significant, especially in cases where the wood ash contains high concentrations of trace elements (Van Ryssen & Ndlovu, 2018). At a trace element concentration in ash of 500 mg/kg, as was the case for Fe, Mn, and Zn in some of the samples, 3% wood ash in a diet would supply 15 mg of Fe, Mn or Zn to a kg of the diet, which would constitute between 30% and 50% of the requirements for livestock (NRC, 1994; 1996). However, due to the large number of variations in mineral and trace element concentrations in wood ash, the effects of trace elements in wood ash in livestock rations are unpredictable. Oso *et al.* (2011) included wood ash from bakeries in diets for broilers and reported that the birds developed leg problems, including swelling of joints and slipped tendon. Consequently these researchers did not recommend the use of wood ash as a Ca source in poultry nutrition. Considering that slipped tendon is associated with Mn deficiency in poultry (Suttle, 2010), low concentrations of Mn in the wood ash as used by Oso *et al.* (2011), viz. 42 mg/kg as compared to a mean concentration of 798 mg/kg in wood ash from subtropical trees (Van Ryssen & Ndlovu, 2018), may indicate that broilers, as reported by Oso *et al.* (2011) in their study, might have suffered from an induced Mn deficiency. These findings emphasize the challenge presented by the wide variation and unpredictability of the trace element concentration in wood ash. Although the concentration of trace elements in feed ingredients is usually not a major determining factor when formulating diets, it can be assumed that wood ash can be a source of trace elements in livestock diets.

Treating animal feeds with ash solutions

The alkalinity of wood ash makes it suitable and effective in treating a deficiency in high-fibre roughages to improve poor digestibility, and also in the detanninification of tannin-rich feedstuffs.

Alkaline treatment of high-fibre roughages has been investigated extensively. Several reviews relate to the use of alkaline treatment to improve the feeding value of roughages for ruminants (Jackson, 1978; Wanapat *et al*., 1985; Nolte *et al*., 1987). Products such as NaOH, urea, and anhydrous ammonia have been used successfully, although they are all corrosive and thus hazardous. Wood ash is a non-corrosive product, and is economical and readily available. Nolte *et al*. (1987) pointed out that wood ash can be used to treat wheat straw and improve its digestibility.

According to Nolte *et al*. (1987) alkaline solutions prepared using wood ash are referred to as solutions of ashes in water or the supernatant fluid when ash is dissolved in water. There are different techniques to prepare these alkaline solutions: Ramirez *et al*. (1991) used 10%, 20% or 30% of wood ash, mixed it with water (w/v) and allowed the ash to dissolve (w/v) until the insoluble material settled out. These authors used a 359 L wood ash solution to soak 60 kg ground maize stover for six hours. The treated stover was dried and fed to ruminants as part of their diet. Imbeah (1999) prepared a 20% (w/v) mixture of wood ash and water and added 4% NaCl to improve its palatability. The mixture was sprinkled on chopped hay (I L per 5 kg hay), mixed, and dried.

Ramirez *et al*. (1992) reported that the DM digestibility of diets containing maize stover treated with 20% wood ash increased by up to 20% in sheep above that of the control group. Nolte *et al*. (1987) found that the treatment of wheat straw with a 30% solution of wood ash for 6 h significantly increased the digestibility of DM, organic matter (OM), neutral detergent fibre (NDF), and acid detergent fibre (ADF) of the straw fed to goats. Treating hay with a 20% wood ash solution also increased the ash content of the treated product by 142%, the Ca content by 443%, Cu by 112%, and Zn by 285% (Imbeah, 1999), thus fortifying the hay with minerals.

In utilizing treated roughages, it should be noted that generally wood ash contains very low concentrations of P, and that the inclusion of wood ash treated feedstuffs in diets could result in a wide Ca : P ratio. When treating hay with a 20% wood ash solution, Imbeah (1999) recorded that the treated hay had a Ca : P ratio of 4 : 1. While Ca, Mg, Cu, and Zn concentrations in the serum of sheep increased over a six-week experimental period, serum P concentration decreased significantly from 98.2 mg/L in week 2 to 60.3 mg/L in week 6, suggesting a reduction in bioavailability of P. *In vitro* digestibility studies by Ramirez *et al.* (1991; 1992) tested the effect of 10%, 20%, and 30% wood ash solutions on the fibre digestibility in sorghum straw and maize stover, respectively. In the study by Ramirez *et al.* (1991) treated straw contained Ca : P ratios of 21 : 1, 71 : 1, and 117 : 1, and when included in a balanced diet in an *in vivo* digestibility study, ratios of 26 : 1, 54 : 1, and 74 : 1 respectively, were recorded. Ramirez *et al.* (1992) treated maize stover and recorded a lower Ca : P ratio, but at the 30% ash treatment level, a Ca : P ratio in a balanced diet was still 15 : 1. Although these were short-term *in vivo* and laboratory investigations, the wide Ca : P ratios demonstrate the potential risk associated with P deficiency if the Ca : P ratio is not corrected when livestock are fed such treated products in long-term feeding regimens. A practical problem would be that P supplementation might be too expensive under subsistence farming situations, thus diminishing the advantages of using such wood ash treated products.

Makkar (2003) reviewed strategies to overcome the detrimental effects of feeding tannin-rich feeds to livestock, and reported that wood ash has the potential to render inactive or remove tannins in feedstuffs. Mohammed & Ali (1988) mixed firewood ash with water at a ratio of 1 : 5 and left it for 24 h. The filtrate was used to treat high-tannin sorghum. The sorghum was soaked in the wood ash extract and then washed several times with water until the washings were clear. The treated sorghum was then sun-dried, ground, and included successfully in a diet for broiler chicks. Kyarisiima *et al*. (2004) mixed 1 kg of hard wood ash with 20 L water and left it overnight. The supernatant with a pH of 11.8 was removed and filtered through cotton cloth before 2 L of the extract was added to 1 kg of high-tannin sorghum grain, soaked for 12 h, and then dried in the sun.

Treatment of oak leaves with a 10% solution of oak wood ash decreased the content of total phenols, condensed tannins and the protein precipitation capacity in oak leaves by 66%, 80%, and 75%, respectively (Makkar, 2003). The pH of the ash solutions was between 10.5 and 11.3. Mohammed & Ali (1988) reported that the soaking of high-tannin sorghum in a wood ash extract improved the performance of broiler chicks to be similar to those which received low-tannin sorghum in their diets. Using a wood ash extract, Kyarisiima *et al.* (2004) reported a 62% reduction in tannins when high-tannin sorghum grain was soaked in the extract, and after germination of the seed an 85% reduction in tannin content was recorded. The treated high-tannin sorghum replaced maize effectively in a broiler diet. However, Tshabalala *et al*. (2013) recorded that different methods of detannification including wood ash were ineffective in improving intake and digestibility of *Vachellia nilotica* fruits by goats. They recommended that detannification methods should be tested on different tree species to establish if they are effective or not.

Conclusion

As is the case with most by-products that can be used in animal nutrition, variation in the nutrient composition of wood ash is high. However, wood ash, and specifically homestead ash, is a resource that is available in most subsistence farming situations and can be considered a source of Ca in animal nutrition. If to be used in feeding programmes, it is recommended that at least the Ca content of the product be measured. To cut cost, it is perhaps worth considering assessing the Ca and mineral content on a regional basis where similar fire-making products are used. The variation in concentration of other elements, especially that of trace elements, is very high and it has been suggested that the bioavailability of these trace elements in wood ash would also be high.

As a non-corrosive alkaline, wood ash has the potential to improve the digestibility of fodder, or to suppress the effect of tannin in plants on the animal. Since a certain amount of ash might be present in the treated products if not washed after treatment, it could result in high Ca : P ratios in the final diet. This would require the supplementation of P to diets containing such treated products. The problem is that under subsistence farming conditions P supplementation might not be feasible.

It is concluded that in resource-poor / subsistence farming situations:

- Wood (homestead) ash can be used as a source of Ca when Ca-deficient products such as cereal in kitchen waste and cassava tuber meal are fed to livestock;
- Although the alkaline treatment of fibrous feedstuffs gave excellent results in *in vitro* and short-term digestibility studies, the high Ca : P ratio in the treated products would require the supplementation of P, which might be unaffordable under subsistence farming conditions.
- Although the concentration of trace elements in ash can vary widely, wood ash can supply highly bioavailable trace elements which subsistence farmers would probably otherwise not be able to supply to their livestock.

Conflict of interest

The author declares that he has no conflict of interest.

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