BIOCHAR ENRICHED FEED FOR ANIMAL PRODUCTION: A FUTURISTIC TREND IN FOOD SCIENCE

Abstract

Biochar-enriched feed for animal production is a new and emerging concept within the realm of food science. Biochar itself is a solid byproduct arising from the pyrolysis process of organic materials, which involves heating organic matter to temperatures equal to or exceeding 300°C with limited or no oxygen. While much attention has been given to potential of biochar for carbon sequestration and its use as a soil amendment, few studies have explored its dietary application in animals. Recent studies, however, stated that biochar holds far-reaching potential and could apply to various farming aspects. Apart from its primary agricultural uses, it looks like a promising ingredient in animal diets. Nevertheless, it is necessary to acknowledge that the utilization of biochar in animal feed is an area of ongoing research and development. Different animal species may react differently to biochar, and the optimal amount and type of biochar to be incorporated into feed formulation are still under investigation. This chapter delves into the fundamental aspects of how biochar affects animal diets, sheds light on its potential uses, and explores the present state of knowledge in this area.

Keywords: Biochar-enriched feed, organic materials, soil amendment

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I. INTRODUCTION

Biochar is a substance produced through the biomass pyrolysis, such as manure, crop residues, and organic waste, in an oxygen-limited environment. This material acts as the precursor for activatedcharcoal (Azargohar& Dalai, 2006) and finds different applications in different fields. Biochar plays a significant role in water purification, biodiesel production, syngas upgrading,organic waste composting, and soil conditioning. Additionally, it is used for remediation of soil, as it enhances the water retention capacity of the soil, increases adsorption ability, and improves diversity of microbes (Cha et al., 2016; Sanchez-Monedero et al., 2018). Since 2010, biochar has been increasingly used as a feed additive in animal husbandry (O'Toole et al., 2016). Biochar used in this context is commonly derived from biomass sources like rice husks (Leng et al., 2012; Phongpanith et al., 2013), woody green waste (Prasai et al., 2016), pine wood chips (Saleem et al., 2018), and jarrah wood (Joseph et al., 2015). To produce biochar by pyrolysis, raw materials undergo heating within a temperature range of 200°C to over 1000°C (Koltowski et al., 2017) in a low-oxygen environment. This process leads to the creation of distinct biochar products with varying properties and functions (Brendova et al., 2012). The functionality of biochar products for feed supplementation depends on important factors such as temperature, heating rate, and residence time (Waheed et al., 2013).

II. BIOCHAR AND ITS HISTORY

Biochar is not a new concept, though the name biochar was coined in 2004 (Neves et al. 2004). Its applications started since time immemorial, for instance, Amazon Basin. In the Amazon rainforest, a scientist (Wim Sombroek) in the 1950s discovered black soil, which was very much more fertile than the nearby area; it was named Terra Preta. It was very important in that century to support agricultural practices because of its highly fertile nature. The soil contains high organic matter, has neutral pH, high nutrient retention capacity, and is more productive as compared to other regions (Lehmann 2007). Numerous theories exist concerning the origin of Terra Preta soil. One hypothesis suggests that ancient societies employed slash-and-char techniques, akin to slash-and-burn practices, to create this dark earth. This process involved clearing and burning vegetation and biomass within a limited area, allowing the remains to smolder rather than fully burn. The charred biomass was then buried under the soil, resulting in the formation of Terra Preta (Talberg 2009). As a consequence of these slash-and-char hypotheses, the method of biochar production has evolved over time.

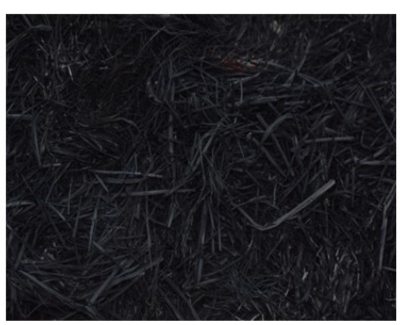

Figure 1: Paddy straw biochar

Figure 2: Biochar enriched feed

III. GUIDELINES FOR USING BIOCHAR AS FEED SUPPLEMENTS

Ensuring precise control of pyrolysis temperatures within a 20% range is of most important in meeting EU regulations for producing biochar used for animal feed. Additionally, biochar products used as feed additives do not require activation processes; the better quality of biochar, which makes them non-toxic and safe for consumption (European Biochar Foundation (EBC), 2012). This desirable characteristic, coupled with the combination of organic residues and biochar, has increased interest among researchers. Now, they are conducting experiments that involve not only blending biochar with manure but also integrating it as a vital component within animal farming systems. It is important that the raw materials used for biochar products as feed additives are derived purely from 100% bio-based materials, such as natural and untreated wood. Moreover, the composition of the raw materials should not vary by more than 15%, as specified by the European Biochar Foundation (EBF) in 2012. The summary of certification criteria for the three different grades of biochar under this standard is as follows,

- Only feedstocks listed in the "positive list" are permissible for biochar production. These feedstocks include leaves, roots, bark, and wood.
- Feedstocks used for biochar production must be free from paints, solvents, and both organic and non-organic contaminants like plastics, electronic scraps, and rubbers.
- Biochar production is limited to forest wood sourced from Europe, and proof of sustainable forest management must be obtained through appropriate standards or certificates.

IV. POTENTIAL BENEFITS OF BIOCHAR-ENRICHED FEED IN ANIMAL PRODUCTION

The idea of incorporating biochar into animal feed is a relatively new concept, but it holds some potential benefits:

1. **Digestive Health:** Biochar exhibits potential as a feed additive, offering the prospect of enhancing the gut health of animals, resulting in improved nutrient absorption and potentially reducing reliance on antibiotics. The practice of supplementing livestock feed

with organic minerals, amino acids, fatty acids, antibiotics, and vitamins is widespread in agriculture to improve immunity, protein intake, growth performance, and overall farming productivity. The adoption of biochar in the agricultural sector is expected to grow at an annual rate of approximately 12.5%. Many studies have reported the benefits of incorporating biochar into animal feed. The addition of biochar to feed leads to enhanced weight gain and feed intake. (Phongphanith and Preston, 2016; Evans et al., 2017and Saroeun et al., 2018). When biochar is fed to swine, total protein, albumin, and low-density cholesterol increases in the plasma, it is also known to reduce stress level by reducing the cortisol contents (Chu et al., 2013). Feeding biochar can also increase the height of villi, cell area, and cell mitosis, due to which feed efficiency increases (Mekbungwan et al., 2008).

2. **Toxin Adsorption:** Biochar shows remarkable capabilities in adsorbing a wide range of toxins and harmful substances. This presents significant potential in animal production, as it can help decrease the presence of specific toxins in animal feed and, consequently, in animal-derived products. Its better adsorption capacity allows it to effectively capture various toxins, including mycotoxins, plant toxins, pesticides, toxic metabolites, and pathogens. Activated biochar, employed as a non-digestible sorbent in adsorption therapy, stands as a vital means of preventing detrimental or lethal effects of orally ingested toxins (McLennan & Amos, 1989; McKenzie, 1991). The useful benefits of biochar can be attributed to one or more of the following mechanisms (Gerlach & Schmidt, 2012):

   - Selective adsorption: Biochar can specifically target certain toxins like dioxins, effectively adsorbing them from the system.
   - Co-adsorption: It can simultaneously adsorb toxins present in the feed, further enhancing its detoxification capabilities.
   - Chemical reaction: Biochar can facilitate chemical reactions that lead to the breakdown and neutralization of toxins.
   - Desorption during digestion: It can release previously adsorbed substances at later stages of digestion, adding to its detoxifying effectiveness.

   A study demonstrated that the inclusion of 2% activated biochar in pelleted aflatoxin-contaminated feed for dairy cows reduced the extractable aflatoxin concentration in the feed by up to 74%. Additionally, it led to a notable reduction of up to 45% in aflatoxin concentration in the milk (Galvano et al., 1996). This finding highlights the potential of biochar in improving the quality and safety of animal products while safeguarding the health of the animal.

3. **Redox Activity:** Biochar has the ability to both accept and donate electrons, making it particularly useful in various applications. In microbial fuel cells, activated biochar serves as both an anode and a cathode (Gregory et al., 2004; Nevin et al., 2010 and Konsolakis et al., 2015. Unlike materials like copper wire that facilitate continuous electron flow, the electrical conductivity of biochar relies on a distinct mechanism known as "discontinuous electron hopping" (Kastening et al., 1997). This unique feature plays a important role in biochar's function as a mediator of electrons in microbial systems, acting as an electron shuttle to facilitate inter-species electron transfer (Chen et al., 2015). Within the gastrointestinal tract, the degradation of feed primarily occurs through the activity of

microorganisms, such as bacteria, archaea, and ciliates. These microorganisms engage in electron transfer during the feed-degrading reactions, either directly to biofilms or indirectly via biofilms to other terminal electron acceptors (Richter et al., 2009; Kracke et al., 2015). The versatile nature of biochar's electron acceptance and donation abilities, coupled with its potential to facilitate electron transfer in microbial environments, makes it a promising candidate for improving digestion efficiency and feed utilization when used in animal nutrition.

4. **Environmental Impact:** Using agricultural residues for the production of biochar presents a promising solution to effectively recycle organic waste, thereby reducing greenhouse gas emissions and achieving a sustainable waste management system. Environmental pollutants, such as Fat-soluble organochlorine compounds (e.g., Polychlorinated dibenzo-p-dioxins (PCDDs), Polychlorinated dibenzofurans (PCDFs), and dioxin-like PCBs), have become pervasive concerns. Notably, these toxic substances frequently find their way into animal feed and subsequently accumulate in the adipose tissue of both animals and humans. Numerous experiments conducted in Japan (Yoshimura et al., 1986; Takenaka, Morita & Takahashi, 1991; Takekoshi et al., 2005; Kamimura et al., 2009) have consistently demonstrated the remarkable adsorption capacity of activated biochar for these organochlorine compounds (Iwakiri et al., 2007). These discoveries highlight the potential of using activated biochar to effectively remove these harmful substances. As a feasible strategy, incorporating biochar into the diet as a food supplement could play an important role in actively reducing industrial and environmental toxins, including dioxins and PCBs (Olkkola and Neuvonen, 1989). By doing so, this approach may lead to a significant reduction in the exposure of both humans and animals to these hazardous compounds, contributing to a healthier and more sustainable environment.

5. **Nutrient Retention:** It can be enhanced by administering biochar into animal feed. This may result in improved digestion, leading to better feed efficiency. The potential benefits of utilizing biochar as a feed additive extend beyond increased feed efficiency; it also offers the possibility of enhancing nutrient availability in manure and safeguarding ground and surface water quality. Farmers reported that the combination of biochar with straw or sawdust bedding at a proportion of 5-10% (volume) resulted in significantly reduced nutrient losses (O'Toole et al., 2016). Additionally, reports from farmers indicated that the addition of 0.1% biochar (by mass) in a liquid manure pit led to a reduction in nutrient losses (Kammann et al., 2017).

6. **Reduced Odor:** Biochar shows promise in mitigating odorous compound emissions from livestock operations associated with manure. In vitro, studies have demonstrated that adding 0.5% and 1% biochar to ruminal liquid led to significant reductions in methane production by 10% and 12.7%, respectively. Additionally, incorporating 0.6% biochar into regular compound feed for cattle could potentially reduce methane formation by 20% (Leng et al., 2013). Furthermore, when combining the same amount of biochar with 6% potassium nitrate, methane emissions were further reduced by up to 40%. These results show the potential of biochar as an effective tool in mitigating greenhouse gas emissions from livestock farming.

V. CHALLENGES AND CONSIDERATIONS

While the concept of biochar-enriched feed for animal production shows promise, several challenges and considerations need to be addressed:

1. **Research and Regulation:** More research is needed to fully understand the potential benefits and risks of using biochar in animal feed. Regulatory bodies would also need to assess and approve the use of biochar in this context.

2. **Feed Safety:** Biochar should be carefully evaluated to ensure it does not negatively impact animal health or human food safety.

3. **Cost and Availability:** Biochar production can be energy-intensive, and its widespread adoption would depend on the effectiveness of cost and the availability of biomass feedstocks (raw material).

4. **Feed Palatability:** Animals may be sensitive to changes in feed composition, and it is important to ensure that adding biochar does not negatively affect the feed intake of animals.

5. **Sustainability:** While biochar is considered a more sustainable approach to waste management and carbon sequestration, it is important to consider the overall environmental impacts of producing and using biochar in large quantities.

VI. CONCLUSION

The utilization of biochar-enriched feed for animal production presents an intriguing and futuristic trend within the realm of food science. This concept holds promise in terms of enhancing animal health, minimizing environmental impact, and promoting waste recycling. However, to fully comprehend its implications and feasibility, further research is imperative. As technology and knowledge advance, it is conceivable that innovative approaches like biochar may play a major role in shaping the future of sustainable agriculture and food production. Incorporating biochar as a feed additive bear the potential to yield various benefits for animal husbandry. It could lead to improvements in animal health, feed efficiency, and overall livestock productivity. Moreover, it has the capacity to curtail nutrient losses and greenhouse gas emissions while simultaneously enhancing manure quality and soil fertility. By complementing other sound farming practices, the integration of biochar could elevate the overall sustainability of animal husbandry. This versatile approach may yield positive effects on numerous parameters, such as promoting growth, aiding digestion, increasing feed efficiency, adsorbing toxins, regulating blood levels, enhancing meat quality, and possibly reducing emissions. In conclusion, the use of biochar-enriched feed has the potential to revolutionize animal production, contributing to a more environmentally friendly and efficient approach to food science in the future. Nevertheless, extensive research and practical implementation are required to fully unlock its benefits and ascertain its role in the pursuit of sustainable agriculture.

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