Vermiculture: a potential role in the management of broiler litter in Australia?

James Turnell

B.Nat.Res.(Hons)

Submitted: 18/06/2007

A thesis submitted for the

Degree of Doctor of Philosophy

Abstract

With increasing human population, the demand for quality animal meat products is increasing, and intensive chicken meat (broiler) production is contributing to some of this demand. A major output from commercial farms is broiler litter (litter) which has relatively high plant nutrient concentrations compared to other animal manures. This makes litter valuable for plant production and hence it is mainly utilised and disposed of on land. However, the suitability of land within cost effective distances from growers is becoming an increasing problem worldwide, with reduced suitability due to potential environmental and bio-security risks. Therefore it is important to develop disposal mechanisms that can provide the industry with an alternative to the direct land application of litter. The present research was undertaken to gain an understanding of the potential role vermiculture could have in the management of litter in Australia.

Vermiculture has the potential to produce both humic rich vermi-compost (vermicast) and meat-meal (vermimeal) from litter. Traditionally vermiculture has primarily been adopted to produce vermicast, a recognised valuable organic fertiliser. However, the production and processing of earthworms into vermimeal is becoming an increasingly viable component. Both of these outputs potentially render vermiculture a value-adding opportunity for the Australian poultry industry, whilst providing an alternative disposal option for litter. That being said vermiculturalists have tended to avoid nutrient rich or 'hot' wastes due the system becoming unstable, resulting in earthworm mortality. Uniquely, this research focused on using fresh litter as the sole food source for earthworms *(Eisenia andrei)* in a batch flow system.

There were three components to this study; firstly defining the litter resource for vermiculture, with a comparison between two integrated broiler processing companies (integrators). Secondly, five laboratory experiments were undertaken to determine if the vermiculture system could operate on fresh litter, and if so at what rate earthworms would process the litter. Thirdly, once the laboratory experiments had been refined a field scale trial was conducted, which used an average commercial shed's worth of litter (70 m^3).

In the first study, the concentrations and variability of chemicals in litter from several farms associated with two Australian integrators were investigated, for suitability of the litter as a food source for earthworms. Previous research had shown that chemical concentrations within litter were highly variable (Marshall et al. 2000, Moore et al. 2000). In contrast this study suggested that the variability in litter from modern evaporative-cooled tunnel ventilated sheds was low. For example, Nitrogen (N) concentrations in litter from three growers operating in Queensland were between 20 and 25 g/kg. Also, the highest within farm variation for N from all farms sampled was 18 % coefficient of variation (cv). The consistency of the litter resource between and within broiler growers indicated that if a vermiculture system could be designed to use fresh litter, then earthworm responses should be similar from one batch of litter to the next.

Secondly, laboratory experiments were designed using an inverted batch flow vermiculture system utilising fresh litter and coconut husk earthworm bedding. Data on earthworm health was also collected using unique health parameters including the dispersion of earthworms on the surface of their bedding (dispersion score) and the rate at which they retracted into their bedding (retraction rate). From previous attempts at using litter it was evident that earthworms were more likely to die when they bunched on the surface (high dispersion score), and when they retracted slowly into their bedding. These health parameters provided a prediction of when mortality was most likely, which enabled management decisions to be made before the system completely failed.

The first three laboratory experiments investigated N management. The first experiment focused on the application and timing of water to improve earthworm health and litter conversion. Results indicated that watering twice daily was ideal in maximising litter conversion and reducing earthworm mortality. Treatments receiving regular watering had lower dispersion scores and faster retraction rates, compared to treatments with extended periods between watering. For example, when decreasing water applications from twice a day to every four days average retraction rates increased from 7.9 to 23.4 seconds. Experiment 2 (ceasing water) indicated that the system was most unstable during the first 8 days and did not require large water applications for the remaining duration of the process. This raised questions about the chemistry of bedding and leachate between stressed and non-stressed systems, which was the focus of experiment 3.

The third experiment investigated changes in total N (TN), electrical conductivity (EC), pH and ammonium (NH_4^+). Measurements were taken from both earthworm bedding and leachate when earthworms were stressed. Total N concentration in earthworm bedding increased during the first five days from 7 to 20 g/kg. More importantly was the 50% lower EC in the least stressed treatment (S1) on day 5 when higher stressed treatments were terminated, due to earthworm mortality exceeding 75%. Furthermore, the heavier the water application the greater the volume of leachate produced and the more NH_4^+ removed. Heavy initial water applications were the most likely factor contributing to system stabilisation. At this stage in the research an a attempt was made to use vermicast derived from litter for earthworm bedding, as it would be available on-site and could improve the economic viability of the system.

The final two laboratory experiments focused on using vermicast earthworm bedding, and included using inoculants supplied by a commercial vermiculturalist in an attempt to improve productivity. Results from experiment 4 indicated that the harvest of earthworms increased from 200 to 400 g and litter conversion time almost halved by using vermicast bedding instead of coconut husk. This outcome was an important finding from a commercial perspective, since an external bedding source (coconut husk) was not required to process litter. Additional chemical analysis of both coconut husk and vermicast bedding indicated that N fluctuated considerably over 24 hours between watering events, again highlighting the importance of regular watering. It was also evident that the EC of leachate increased to above 30 dS/m on day 10 and then decreased to 6 dS/m by completion. This initial spike in EC was evidence that salts including NH_4^+ were the most likely cause of earthworm mortality during the early stages of the process. In the final laboratory experiment inoculation of earthworm substrate was investigated. Although it was expected that by increasing microbial populations in the litter the system would stabilise faster, results from experiment 5 suggested inoculant did not improve the rate of litter conversion or the biomass of earthworms.

Finally, a field trial was conducted using a full commercial shed load of litter (70 m^3) as an input for a batch flow vermiculture system. This litter was successfully converted into vermicast within 108 days and an estimated 2000-4000 kg of earthworms were available for harvest. Combining the field trial results with those conducted in the laboratory, enabled the development of a model for the broiler industry to determine the potential outputs from this system, and its value-adding potential. Based on the vermiculture process operating at optimum conditions it was not unreasonable to assume that from 70 m^3 of litter, approximately 44-52 m^3 of vermicast and 9,450 kg of earthworms could be sold off-site. The results so far are most encouraging.

Acknowledgments

This study would not have been possible without the support and funding Australian Poultry CRC and Mr Wayne Fauser (Thewormman®). I truly appreciate their assistance, guidance and enthusiasm in solving the hurdles encountered throughout the project. I would also like to thank my two wonderful supervisors, Associate Professor Richard Faulkner and Associate Professor Geoff Hinch, who were always there. I would like to thank Dr Simon Murray, who was initially my supervisor, and kept me focused on timelines. I am grateful for the technical assistance from School of Environmental Science and Natural Resource Management and the School of Rural Science and Agriculture. I especially acknowledge the technical help from Marion Costigan, Leanne Lisle, Barbara Gorham and the computing support from Jim O'Neill.

I would like to express my gratitude to Milton Curkpatrick and Peter Robinson of UNE Rural Properties for allowing access to Laureldale Research Station and providing fencing for the field trial. Thank you to the broiler integrators for organising litter for my experiments and collaborating with me to undertake sampling. I sincerely thank Adam Downey and Nic Rodgers, former PhD students for their help and encouragement, especially regarding statistical advice. A very kind thankyou to current and previous participants of our poultry research group at UNE, their support has been wonderful.

A special thankyou to my lovely wife Janelle Wilkes, who supported me when I needed it most and encouraged me to trust my instincts. I would also like to thank my parents and extended family for finding the time to listen, thankyou.

Table of contents

List of figures

List of tables

Abbreviations and Acronyms

ATP (Adenosine triphosphate)

ADP (Adenosine diphosphate)

BSE (Bovine spongiform encephalopathy)

CAFO's (Confined animal feeding operations)

CEC (Cation exchange capacity)

C:N (Carbon to nitrogen ratio)

cv (Coefficient of variation)

DNA (Deoxyribonucleic acid)

DO (Dissolved oxygen)

EC (Electrical conductivity)

GEV (Gross energy value)

GHGE (Greenhouse gas emissions)

H5N1 (Highly pathogenic avian influenza)

ICP (Inductive coupled plasma)

Integrators (Integrated broiler processing companies)

Litter (Broiler litter)

LSD (Least significant difference)

NLC (Nutrient loop closure)

NO_x (Nitrogen oxides)

NSW DEC (New South Wales Department of Environment and Conservation)

OC (Organic carbon)

ORP (Oxidation-reduction potential)

RNA (Ribonucleic acid)

SE (Sample error)

SOM (Soil organic matter)

T (Metric tonne)

TC (Total carbon)

TE (Trace elements)

TKN (Total kjeldahl nitrogen)

TN (Total nitrogen)

TP (Total phosphorus)

USEPA (United States Environmental Protection Agency)

UNE (University of New England)

UV (Ultraviolet)