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Systematic Map Protocol

Title
What is the existing research evidence relating to different valorisation methods of chicken manure? A systematic map protocol

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Chicken litter, broiler manure, layer manure, composting, manure treatment

Background
The poultry industry is growing fast due to overwhelming demand for chicken meat and eggs [1,2]. Globally, annual chicken meat production increased from 7 to 119 million tonnes, while egg production increased from 14 to 86 million tonnes between 1961 and 2020 [3]. Chicken production for meat is projected to have the highest growth rate at 121% between 2005 and 2050, compared to potential increases for egg (65%) and beef (66%) demand [4]. Consequently, increased production of chicken products will lead to an abundance of manure produced. Therefore, the high demand for chicken products has led to the growing issue of manure disposal [5]. Chicken manure is rich in nutrients such as nitrogen and phosphorus and it is traditionally used untreated as fertilisers through direct land application [6]. Other methods practiced for using chicken manure include composting, anaerobic digestion, incineration etc. [7]. New emerging methods for valorisation of chicken manure include processes such bioethanol production through simultaneous saccharification and fermentation [8] and bioponics [9]. However utilising chicken manure without any prior treatment leads to environmental pollution such as eutrophication [10]. Due to these factors, there is a need to investigate alternative strategies for handling chicken manure which when implemented should provide benefits commercially as well as environmentally. To the best of our knowledge, there is no systematic review or map published on this subject and this is an original review. The purpose of this systematic map is to investigate how to transform chicken manure to value added products, make chicken manure more marketable and to reduce the purchase of artificial fertilisers. This will help to reveal areas for potential future research by highlighting gaps in the scientific literature. Furthermore, a potentially sustainable novel strategy to valorise chicken manure could be identified and/or optimisation of established methods could be highlighted.

Theory of change or causal model
Chicken manure contains nutritional elements such as nitrogen and phosphorus and contaminants such as pathogens which influence environmental health. The underlying assumption of this protocol is that there are technologies that can recover or reduce nutrients and eliminate pathogens from chicken manure which can then be used in environmentally friendly ways to produce value added products. This research is expected to detail which valorisation methods are used for chicken manure with or without pre-treatment.

Stakeholder engagement
This protocol was developed in response to questions from the School of Sustainable Food and Farming, based on discussions with their industrial stakeholders. The review question was refined after discussion with a Morrisons representative from the School of Sustainable Food and Farming.

Objectives and review question
The aim is to investigate the current research evidence relating to valorisation strategies of chicken manure in order to inform future research that would possibly help to identify a novel strategy which could be then further researched for its potential sustainability. The primary question for this systematic map is: What is the existing research evidence relating to different technologies/processes for producing value added products from chicken manure whilst mitigating pollution? Secondary questions: What are the comparative costs of different valorisation methods? What by-products are there? In what state is chicken manure more effective as fertiliser?

Definitions of the question components
Population(s): chicken manure. Intervention/exposure(s): technologies/processes that are used for valorisation/nutrient recovery/pollutant reduction (e.g. pyrolysis, drying, pelleting, bioponics, composting, incineration, application to land, anaerobic digestion). Comparator(s): None, before technology use, alternative technologies. Outcome(s): value-added products (biochar, fertiliser, biogas) ammonia emissions, pathogen load, leaching level (nitrates, phosphates, pathogens), soil carbon sequestration, other environmental impacts.

Search strategy
A database will be produced using the following methods and will document the publications assessed. The methods used are based on James et al. (2016) [11] and the Collaboration for Environmental Evidence Guidelines [12]. ROSES reporting standards [13] have been adhered to and can be found in additional file 1. The searches for both published and grey literature will be conducted using the sources and search string defined below. The results from each search will be imported to reference manager Endnote online and details of each search will be recorded including date, time, number of results, and precise search string used. There will be no search restrictions regarding the published date of articles as there may be relevant historical and modern literature, but the publication language will be restricted to English. Search terms were identified from the PICO analysis and a list of benchmarking articles is discussed in section “Comprehensiveness of the search”. The search string was developed using a scoping study found in additional file 2. The following databases and platforms will be searched:

Bibliographic databases
The search for relevant literature will be conducted using the following bibliographic database: 1. Web of Science 2. CAB Abstracts (both accessed through Harper Adams University subscription). The search string to be used is as follows: ("chicken manure" OR "chicken litter" OR "chicken waste" OR "broiler* manure" OR "broiler* litter" OR "broiler* waste" OR "layer* litter" OR "layer* manure" OR "layer* waste") AND (valoris* OR valoriz* OR treatment* OR technolog* OR process* OR pyrolysis OR drying OR pelleting OR bioponics OR composting OR incineration OR "anaerobic digestion" OR "hydrothermal liquefaction" OR fermentation OR "nutrient* recovery" OR "nutrient* stripping").

Web-based search engines
In addition, we will search the following for any new technologies related to chicken manure valorisation: 1. Poultry World 2. Farmers Weekly. The search terms used will be simpler such as “chicken manure treatment” depending on the website.

Organisational websites
A further search will be conducted using the following organisational websites: 1. .gov.uk (DEFRA). 2. AHDB. 3. The British Poultry Council. The search terms used will be simpler such as “chicken manure treatment” depending on the website.

Comprehensiveness of the search
The comprehensiveness of the search string was examined in the scoping study using three benchmarking articles known to be relevant to the map, which can be found in additional file 3.

Search update
N/A

Screening strategy
All articles returned by the searches will be screened using EPPI-Reviewer. Primary screening will be by title to remove duplicates. The quantity of duplicates will be noted however these articles will not be recorded in a separate file. The remaining articles will then be screened against the inclusion criteria by title, then by abstract. Both relevant grey and published literature will be considered for inclusion. Where available and if necessary, the full texts will then be screened. Where full texts are not available through Web of Science and CAB abstracts, they will be accessed using HOLLY (Harper Adams University Online Library). Articles where the full text is inaccessible will be included if the abstract provides sufficient information to satisfy the inclusion criteria. Secondary research, such as reviews and meta-analyses, will be included in a separate file and will be used as a source for additional primary research. Any articles identified by these sources which satisfy the inclusion criteria will be added to the systematic map. Should the quantity of included studies exceed the limitations of the timeframe, the eligibility criteria will be reviewed and made more restrictive.

Eligibility criteria
The eligibility criteria were determined based on the PICO analysis, stakeholder interests and the time restrictions of the study. Eligible populations: chicken manure, chicken litter, chicken waste, broiler manure, layer manure. Eligible interventions: composting, pyrolysis, anaerobic digestion, bioponics, hydrothermal liquefaction, fermentation, application to land, drying, any technology used for recovery of nitrogen and phosphorus. Eligible comparators: no technology used, alternative technologies. Eligible outcomes: Reuse of nitrogen, phosphorus and carbon compounds, vegetable growth, ethanol production, fertiliser production, biochar production, biogas production. Eligible types of study design: All. Eligible languages: English. Geographical limits: Worldwide. Time period: All.

Consistency checking
The articles will be screened against the inclusion criteria by title, then by abstract by first author. A random sub-set of 5% or a minimum of 100 articles of those articles will be used to check consistency of the screening by another author who will screen the articles to abstract against the inclusion criteria. First author will conduct the full text screening and a random sub-set of 5% articles will be screened by another author who will screen the articles to full text against the inclusion criteria. The size of this subset may decrease if the quantity of articles is too great for the timeframe. Cohen’s Kappa coefficient will be used to determine the consistency of decision making and a value of greater than 0.6 will indicate acceptable agreement. Where authors have differed, the inclusion criteria will be reviewed and adjusted accordingly.

Reporting screening outcomes
A ROSES flow diagram will be produced to report the outcome of the screening. Articles excluded at

title and abstract will be detailed in one file, while another separate file will record articles excluded at full text with explanations of their exclusion. Any deviations from this protocol will be reported and explained.

Study validity assessment
As it is a systematic map, critical appraisal will not be carried out.

Consistency checking
N/A

Data coding strategy
If the timeframe, quantity of articles and access allows, full text data will be extracted according to the data coding strategy set out in additional file 4, otherwise studies will only be coded to abstract. All studies will have the following meta-data recorded: • Bibliographic information • Technology/treatment/valorisation method name • Short description of technology • Before technology/alternative technologies • Valorisation outcome (e.g. fertiliser, biochar, biomethane, hydrogen) • Short description of the valorisation outcome • Cost implications of the method • By-products produced in the process • Recovery/mitigation of nutrients/pathogens • Short description of recovery/mitigation • Comments

Meta-data to be coded
The full data coding strategy can be found in additional file 4.

Consistency checking
Coding will be performed by the first author, with a subset of 5% of studies checked for coding consistency by all authors. Should there be substantial disagreement, the coding criteria will be reviewed and a further subset of 5% of studies will be rechecked for consistency. This will be repeated until the consistency reaches a minimum of 90% similarity. Other missing relevant information will be coded as “Not specified”, because the timeframe does not allow for contacting authors for information, and information that does not apply to a specific study will be coded as “NA”.

Type of mapping
A full written report will be produced to document the methods and results of the research and will accompany the systematic map database. The searchable database will be produced using Microsoft Excel and will contain a data dictionary, all included studies and all available details from the coding strategy. This will be published as a supporting file with the systematic map report.

Narrative synthesis methods
Descriptive statistics will be used to characterise the systematic map, while evidence clusters and gaps in the literature will be identified via heat maps: tables of two variables showing the number of studies examining their interaction.

Knowledge gap identification strategy
The systematic map database will enable clusters to be identified. The final report will detail any gaps or clusters identified by the heat maps described above and will include any relevant recommendations.

Demonstrating procedural independence
SA does not have previous publications relevant to this research. The random subsets of articles NR and MK will check for consistency will not include their own publications.

Competing interests
The authors declare that they have no competing interests.

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This project is funded by the School of Sustainable Food and Farming. This protocol and review questions were developed in response to questions through discussion with Morrisons on behalf of the School of Sustainable Food and Farming.

Author's contributions
NR and MK conceptualised the primary question, commented on and finalised the manuscript. NR proposed the systematic map approach. SA drafted the initial protocol, performed the scoping study, and wrote the final manuscript. All authors read and approved the manuscript.

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