



Deposited via The University of Sheffield.

White Rose Research Online URL for this paper:

<https://eprints.whiterose.ac.uk/id/eprint/193027/>

Version: Published Version

Article:

Chen, S. (2022) British dairy farmers' management attitudes towards agricultural plastic waste: reduce, reuse, recycle. *Polymer International*, 71 (12). pp. 1418-1424. ISSN: 0959-8103

<https://doi.org/10.1002/pi.6442>

Reuse

This article is distributed under the terms of the Creative Commons Attribution (CC BY) licence. This licence allows you to distribute, remix, tweak, and build upon the work, even commercially, as long as you credit the authors for the original work. More information and the full terms of the licence here:

<https://creativecommons.org/licenses/>

Takedown

If you consider content in White Rose Research Online to be in breach of UK law, please notify us by emailing eprints@whiterose.ac.uk including the URL of the record and the reason for the withdrawal request.

British dairy farmers' management attitudes towards agricultural plastic waste: reduce, reuse, recycle

Dr Shuhan Chen ^{†*}



Abstract

Agricultural plastic waste from nonpackaging polymers, such as those used in silage production, constitutes the majority of the UK's agricultural plastic waste due to inadequate management. This study included online and telephone interviews with 12 British dairy farmers (nine from England, three from Wales) to understand the use of non-packaging plastic in silage production on British dairy farms. It examined their current silage production techniques and agricultural plastic waste management behaviours and highlighted the challenges of reducing plastic waste on dairy farms through the lens of circular economy. The findings show that UK dairy farmers have adhered to the mantra of reduce, reuse and recycle. They use silage clamps for high volumes of silage production, try to reuse some used silage sheets and express a strong interest in having their waste plastic collected and recycled. However, the lack of effective agricultural plastic waste collection services, inequitable enforcement of plastic waste management regulations and rising costs of waste plastic collection in the UK make it difficult for them to recycle effectively.

© 2022 The Author. *Polymer International* published by John Wiley & Sons Ltd on behalf of Society of Industrial Chemistry.

Supporting information may be found in the online version of this article.

Keywords: British dairy farming; non-packaging plastic; agricultural plastic waste; waste hierarchy

INTRODUCTION

Along with the growing demand for high-quality food, the use of agricultural plastic for farming production has become so prevalent that it has its own term: plasticulture.¹ The agricultural plastic market was worth USD7.48 billion in 2016 and is expected to grow by more than one-third and reach USD10.57 billion by 2022.² In Europe, agricultural plastics account for 3.3% of worldwide plastic production, totalling 12.2 million tonnes in 2018.² According to Agricultural Plastic Environment (APE) Europe, 722 kt of agricultural plastic was used in Europe in 2019,³ of which, 45% (325 kt) was used for crop production and 55% (397 kt) for livestock production. Notably, 76% of the total agricultural plastic in the European market was plastic films; 37% (267 kt) of these were stretch and silage films and 28% (203 kt) were plastic films used for greenhouse and mulching.³ Although stretchy silage film represents more of the total than films used for crop production, mulch films have received more attention in existing scientific studies. For instance, research indicates that mulch films come into direct contact with soil, which makes the film highly contaminated, difficult to collect and recycle, and increases the likelihood of plastic debris being left in the soil, which increases the agricultural plastic footprint and presents a major threat to farming sustainability.³⁻⁵ Due to geographical differences, farmers in northern Europe use more agricultural plastic for silage production.^{6,7} Meanwhile, APE UK data reveal that plastic films used for producing and storing silage account for the majority of non-

packaging plastic used on British farms.⁸ In 2019, used bale wrap (44 kt) accounted for almost half of the non-packaging agricultural plastic waste (82 kt) generated on British farms, followed by mulch films and silage sheets.⁸ Therefore, the study reported here addressed a research gap by examining the non-packaging plastics used for silage storage and production in the UK, with a particular emphasis on British dairy farms.

As in other industrialised countries, the trend of fewer dairy farms operating with a greater number of higher-yielding cows is common in the UK.^{9,10} For example, in the UK, the number of registered dairy farms decreased by 67%, from 35 700 in 1995 to 11 900 in 2020, while herd sizes rose by 28%.⁹ The reduced numbers of dairy cows and dairy farms have been countered by increasing average cow yields, which have risen from 4100 to 8200 L since the 1970s.⁹ To accommodate the year-round demand for milk, British dairy farms have changed their management systems, such as by curtailing grazing time and increasing

* Correspondence to: S Chen, London College of Communication, Elephant and Castle, London SE1 6SB, UK. E-mail: drshuhanchen@gmail.com

[†] Dr Shuhan Chen carried out this work while a postdoctoral research associate at the University of Sheffield. Currently, she is a lecturer in communication in London College of Communication at the University of the Arts London, UK.

University of Sheffield, Sheffield, UK

indoor feeding.¹⁰ For instance, research indicates that up to 95% of UK dairy farmers utilised grazing as part of their dairy management strategy in 2005, but this figure had dropped to 92% in 2013.¹⁰ In the meantime, Shortall and Lorenzo-Arribas¹¹ found that 19% of Scottish dairy farmers who responded to a survey did not graze their cows. Increased indoor feeding as well as the greater energy needs of high-yielding cows all contributed to a rise in the demand for supplemental feed and quality silage production on British dairy farms.^{10,11}

Silage is a type of animal fodder that is widely used on livestock farms in Europe; it is typically prepared from grass and whole crops and stored in bunker silos or wrapped bales,^{12,13} which are known as silage clamps and silage bales. Compared with fresh crops or hay, silage effectively minimises the nutrient loss from harvest to storage, preserves more dry matter, offers more energy and has a high nutritional content that is highly digestible.^{14,15} Additionally, it offers greater flexibility in ration composition, which enables animals, particularly dairy cows, to consume a regular diet. The quality of silage affects not only the health of the livestock but also the quality and amount of milk produced.^{16–18}

Plastic is critical for the production of high-quality silage as it helps to create an anaerobic environment, accelerate forage acidification and prevent spoilage microorganisms and dry matter loss of the stored silage.^{19,20} Silage clamps often have three silo walls and may or may not have a roof. For silage production, British dairy farmers line the walls of the silo with plastic films and then seal the clamp by covering the top with plastic films, tensile-strengthened plastic sheets and then some weight, frequently tyres. Meanwhile, farmers bale the silage with net wrap and then wrap the bales with stretchy, ultraviolet-light-resistant plastic films.^{20,21} While about 70% of the non-packaging plastic used for silage production on British dairy farms is low-density plastic, it is frequently non-biodegradable, difficult to recycle and single use, which can create substantial environmental problems if handled improperly.^{4,21} For example, Briassoulis *et al.*²² and Steinmetz *et al.*²³ found that burning agricultural plastic waste on farms results in the discharge of toxic compounds and air pollutants. The authors of a study of plastic pollution in rural communities observed that burying waste plastic might contaminate soil and groundwater and potentially degrade soil quality.²⁴ Additionally, dumping agricultural plastic waste in open areas might contribute to aesthetic pollution and landscape degradation.²⁵

Currently, in the UK, a significant amount of used agricultural plastic is not collected or is recycled improperly. For example, APE UK data showed that British farms generated about 82 kt of non-packaging agricultural plastic in 2019, but only 27 kt of waste plastic was collected, and just 32% of that collected waste plastic was recycled.⁸ British farmers have been blamed for improper agricultural plastic waste management behaviours. The Environment Agency of England found that improper plastic management behaviours such as waste fly-tipping, burning and burying are prevalent on British farms, and some farmers even attempt to export contaminated agricultural plastic waste, especially silage wrap, to other countries, despite the prohibition of all of these behaviours and the potential for heavy fines or imprisonment.^{26–28}

Thus, specific guidelines have been set for British farmers to minimise waste plastic on their farms. An example are the Waste Regulations 2011; the Department for Environment, Food and Rural Affairs has released guidelines on applying the waste hierarchy to commercial, industrial and agricultural plastic

management.²⁹ The waste hierarchy lists waste management options according to their environmental impact.²⁹ It gives top priority to preventing waste; when waste is generated, reuse is encouraged, followed by recycling, recovery and finally disposal, the least recommended option.²⁹ Currently, the UK government advocates reuse and waste reduction to address packaging plastics, rather than the throwaway mentality fostered by the market, as well as meeting statutory recycling requirements.³⁰ However, virtually no published information is available in the public domain to explain the optional behaviours that British dairy farmers can follow to minimise non-packaging agricultural plastic waste on their farms.

This study aims to fill in this research gap by exploring the attitudes of British dairy farmers towards adhering to the reduce, reuse and recycle mantra to minimise the amount of agricultural plastic waste generated from silage production. The methods section includes an explanation of the research methodology. The findings section includes the key themes identified for this study. Then the discussion section compares the hurdles that different consumers face in terms of managing plastic waste and makes recommendations for policymakers and industry so as to help farmers handle agricultural plastic waste properly. Finally, the conclusions section sums up the key findings of the study and points out directions for future research.

METHODS

This study followed the constructivist paradigm and applied a qualitative research methodology to attain its purpose. This paradigm asserts that people develop their knowledge through experience, which can be subjective, personal and flexible.³¹ In this paradigm, researchers develop meanings of social phenomena and understand the ways in which sociocultural context affects participants' experiences and shapes their knowledge of specific topics by interacting with them.^{31,32} The interaction frequently starts with an open inquiry; hence, semi-structured interviews were used for data collection. Semi-structured interviews follow a flexible approach and often include follow-up questions, probes and remarks. This method allows researchers to collect open-ended data and investigate participant ideas, emotions and opinions on a specific topic while also allowing them to delve deeply into personal and sensitive issues.³³ This method helps to explore dairy farmers' current agricultural plastic waste management behaviours and attitudes toward adhering to the reduce, reuse and recycle routes so as to minimise agricultural plastic waste on their farms.

This project received ethical approval from the University of Sheffield (Ref. 0322303) in April 2020. Then call for participants information was advertised on a variety of online platforms such as Facebook, Twitter, [Farming.com](https://www.farming.com) and Women in Dairy. Online recruitment represented a balance between the constraints of data collection and analysis as well as the need for a representative sample of behaviours and their determinants.³⁴ However, due to the interruption of the COVID pandemic lockdown, the target audiences' response rate was low. After vigorously marketing the participant recruiting material for almost 3 months, 12 British dairy farmers (eight male and four female) replied to the web advertisement and participated in the online interviews (three from Wales and nine from England). This study received no responses from dairy farmers in Scotland or Northern Ireland.

Each interview lasted up to 60 min and was done through an online meeting platform or by phone, depending to the

participants' preferences. With the participants' permission, interviews were audiotaped and subsequently transcribed in three steps: (i) listening without transcribing, (ii) listening while transcribing and (iii) listening again to refine the transcription.

Following the thematic systematic guide introduced by Braun and Clark,³⁵ the refined transcripts were analysed and phenomenologically coded, grouped and then interpretative themes that were dialectically linked to the text were generated. The four themes of British dairy farmers' plastic usage for silage production and their attitudes towards adhering to the concept of 'reduce, reuse, recycle' to minimise plastic waste on farms are presented below.

RESULTS

Among the 12 dairy farmers who took part in the interviews, eight were male and four were female, with two female participants indicating that they were the managers of their dairy farms. Although this finding suggests that men continue to play a dominant role on dairy farms, a study found that 84% of farm-holders in England are male and 16% are female, a gender ratio that applies to the rest of the UK.³⁶ It also demonstrates women's rising impact in the dairy business, since they both run the farm and actively share their knowledge. Besides, it is worth noting that the average age of the participants is well below the average age of UK farmers, at 48 and 58 years old,³⁷ respectively, with the youngest dairy farmer being 35 and the oldest being 55. Additionally, there has been a significant decline in dairy farmers in England and Wales in the past decade.⁹ By focusing on English and Welsh dairy farmers, this study explored their current agricultural plastic waste management behaviours and identified three barriers in following the reduce, reuse and recycle mantra.

Silage clamps are the main silage production method

All participants in this study indicated that they use both silage clamp and baled wrap for silage production. Plastic is widely used in silage production, from covering the clamp to netting and wrapping bales, and eight participants described such practices as traditional silage production methods on their farms. For instance:

As far as I can remember, we use the plastic for silage production, I could not think of other ways for silage production. (Farmer 1, male, Yorkshire)

I don't know why we use the clamp; it was there since I came to this farm after marrying my husband; it was like this for nearly twenty years now. (Farmer 2, female, Somerset)

British dairy farmers started using plastic for silage production in the 1960s. The durability and low cost of plastic make it the perfect material to create an anaerobic environment for forage fermentation.³⁸ Outdoor silage clamps and bales became the main ways to store silage on British farms. Dairy farmers would choose a silage production method according to their needs; farm size, herd size and different production mechanisms would all contribute to determining the appropriate choice.

Dairy farmers explained that price, productivity and flexibility are three key reasons that affect their silage production decision. For instance, all of the dairy farmers in this study stated that making silage in clamps is cheaper, can produce a larger amount of

silage and is easier to manage compared to baled silage. All of the dairy farmers were aware that silage clamps use less plastic and generate less plastic waste, which can reduce farm costs. Clamps also increase the variety of feed; four participants stated that the components of their silage are more suitable for clamped silage production as prickly-stemmed crops would puncture wrapped bales. Despite these advantages, the dairy farmers emphasised that they did not plan to stop making baled silage as it offers flexibility for silage production and feeding and may be better quality than clamped silage.

Baled silage is easier to feed out small amounts in spring and autumn, without high wastage from the clamp. (Farmer 3, male, Yorkshire)

Good for feeding bales at the start or end of winter when dairy cows are grazing and only need smaller amounts of silage a day – it means we can open one or two at a time instead of opening the pit and therefore reducing the amount wasted by air getting into clamp. (Farmer 10, male, Yorkshire)

Reduce: it depends on farm and herd size and cattle breed

As mentioned previously, dairy farms are changing their feeding systems to improve efficiency. In response to the increasing indoor feeding time, the researcher asked about the possibility of extending dairy herds' outdoor time to eliminate the need for silage for indoor feeding. Farmers from different places had different opinions on this suggestion. Dairy farmers from Wales emphasised the effect of the unpredictable weather and herds' adaptability and suitability to harsh weather.

The weather is unpredictable; we make as much as silage we can in case the weather is not good next year. (Farmer 4, male, Cornwall)

It depends on the breed of the cattle; some breeds cannot stay outside too long in wintertime. (Farmer 2, female, Somerset)

For dairy farmers, silage production is a way to make full use of natural resources, so, although they may have produced more than they need, they can either keep it for next year or sell it to other farmers. Therefore, instead of minimising the cost of silage production and the use of plastic, thus risking producing insufficient silage, farmers prefer preparing sufficient or excess feed for their dairy herds. Meanwhile, as March *et al.*¹⁰ noted, British dairy farmers have changed their farm management systems to maintain dairy cows' high yields, such as increasing indoor feeding. For instance, a high-yielding cow's performance can require up to five times the amount of energy it needs for maintenance. Therefore, grazing will not meet the needs; quality silage and additional feeding are required.¹⁰

Farmer 8 (male) from Derbyshire explained that his farm increases grazing for calves, which not only reduces the need for silage production but also reduces the cost of building shelters and clamps and the labour cost to make feed for and deliver it to the calves. This also dramatically reduces the use of plastic for silage production.

We increase the grazing time of calves, which reduce the use of silage dramatically and reduce the cost of purchasing; also, the trouble to dispose of plastic waste. (Farmer 8, male, Derbyshire)

Farmer 8 mentioned that he had adopted this feeding system some time ago and explained that calves are better at bearing the winter cold than lactating cows. He also noted that such feeding systems are popular in New Zealand when asked why he thought they were not prevalent in the UK. He explained that not all dairy farmers are willing to explore and learn new information or interested in change. His farm is relatively new, and he has enough space to conduct such experimental work, while for most dairy farmers, reducing silage production to reduce plastic usage is not feasible; instead, they suggest there may be a chance to reuse the plastic.

Currently, I could not think of any other ways to reduce the use of the plastic ... maybe reuse if possible. (Farmer 2, female, Somerset)

Reuse: farmers have tried, but it is difficult

In terms of reuse, all participants pointed out the impossibility of reusing the netting and plastic films used for baled silage.

Can't do it, silage bale wrap cannot be reused. (Farmer 2, female, Somerset)

The key reason that stretchable plastic baling film cannot be reused is that farmers frequently cut the bale wrap to access the silage, which makes the wrap unsuitable for reuse. In addition, stretchable silage wrap is frequently contaminated with soil, water and silage, and the contaminants can amount to up to 50% of the total weight of the material collected, which reduce its value either for reusing or for recycling.¹

Only three participants stated that they had started reusing plastic sheets from silage clamps and noted that they only reuse some of the used plastic sheets for clamped silage production. For instance, dairy farmers may use plastic films or thin plastic sheeting to cover the clamp or to line the clamp walls, and then use durable, heavy-weight, thicker plastic sheeting to seal the clamp. Then, farmers will reuse the thicker plastic sheets and dispose of the thinner plastic film. Alternatively, farms that use two layers of thin plastic sheeting to cover the clamp and one layer to line the clamp walls may reuse the top plastic film as the side lining the next year.

Sometimes, depends on how it has been looked after in the winter; if we do reuse it, we only use it as side sheet; we always put new top sheet on. (Farmer 8, male, Derbyshire)

Farmer 8 further suggested that reusing plastic covers was not as easy as reusing single-use plastic bags from the supermarket.

You need to protect them well, roll them up while using, avoid machinery damage and keep them clean, they [these practices] are not easy. (Farmer 8, male, Derbyshire)

However, not all of the dairy farmers in this study employed such behaviours, especially those who run farms with larger herd sizes, have more than one clamp to manage, or because of the farm's

location. For instance, Farmer 4 (male) operating a dairy farm in Cornwall explained his concerns about the frangibility of used plastic sheeting and, especially, the effort and labour cost to ensure the plastic sheeting would remain intact after contacting with the silage and a year of exposure to outdoor conditions. Because collecting, cleaning and storing used plastic sheeting increase both the labour and space costs, these practices could be more expensive than purchasing new material, as well as increasing the risk of poorly sealing the clamp and reducing the quality of the silage produced.

You must have not worked on the farm ... the strong wind, exposing in the sun, the rainwater, the crop piercing, it is not easy to maintain them. If it is broken the whole area of silage can be damaged and may contaminate the silage. Compare with the plastic price, the silage is more important, doesn't worth to take the risk. (Farmer 4, male, Cornwall)

Farmer 7 (male, Somerset) agreed with this statement and noted that farmers do not want to take the risk of reusing plastic film and losing their silage, as replacing the silage would cost more than simply buying new plastic.

It would be great if you can do it ... if you have strong wind, it will become dirty, then recycling collectors will not take it ... we would reuse if we can, but you can't risk. Also, the labour to collect them and space to store them for next year could cost more than buying new plastic. (Farmer 7, male, Somerset)

Farmer 12 (male, east Essex) noted that he tried to improve the reuse rate by changing to a different plastic brand; however, he also heard that such new materials were not recyclable, which affected his decision to continue using this brand or not.

We try to reuse sheet, but this is not always possible as some types of sheets are difficult to roll up. Some of the double sheets, those with an outer sheet and film, definitely cannot be reused as the film separates from the outer sheet; this year we are trying a new sheet for grass silage called Silostop, described as the ultimate oxygen barrier film. However, some people have said this cannot be recycled. (Farmer 12, male, east Essex)

Recycle: farmers would like to pay for recycling, but there are not enough collectors

Compared with reduction and reuse, all of the dairy farmers in this study expressed more interest in sending their agricultural plastic for recycling. For instance, two dairy farmers emphasised that they would rather pay more to find a collector who would ensure that their plastic waste was recycled; for instance, Farmer 2 (female, Somerset) stated that she started using a recycling collection service instead of landfilling services after becoming aware of the environmental benefits of recycling over landfilling.

We used to send the waste to the landfill site, then I learnt the FarmXS and started using them ... I think it is better to have the plastic recycled. (Farmer 2, female, Somerset)

However, Farmer 3 (male) from Yorkshire expressed his concerns over inequivalent infrastructure services in different regions in the UK.

I think as a farmer, we are quite lucky, we got a local waste collector who can collect from us; I know farmers in other parts of the country who really struggle to have their waste collected. (Farmer 3, male, Yorkshire)

Farmer 5 (female), from Wiltshire, noted that there were no recycling collection services in the area; therefore, she rented a skip from a company that comes to collect the filled skip every few months. She thought such a service was easy and, as long as the farm can be kept clean, hoped to continue using the service. However, she also stated that increasing collection fees forced her farm to change skip companies every 1 or 2 years.

It is easy system, just pay for the skip; as long as we discipline ourselves, no rubbish, just plastic, hopefully it is valuable to the waste collector ... We don't really know what they do with the plastic ... we change the service quite frequently; they can be cheaper this year, but they can be really expensive ... then we have to change. (Farmer 5, female, Wiltshire)

Despite all dairy farmers having hired waste collectors or rented skips to collect agricultural plastic waste on their farms, they noted that they have limited information about how these waste collectors truly manage the collected waste plastic. For instance:

We can put all kinds of agricultural plastic waste in the skip, they [skip collectors] charge by each skip, therefore, we try to fill in the skip as full as possible before we phone the collector, which is easy and cheaper. (Farmer 8, male, Derbyshire)

We have a contractor who comes and collects the plastic waste ... we pay these collectors annually, while we don't know how they manage these plastic waste, maybe to landfill. (Farmer 1, male, Yorkshire)

Keeping agricultural plastic waste clean and dry enough to recycle remains a great challenge for farmers seeking to improve the agricultural plastic recycling rate on their farms. On the one hand, dairy farmers complain about the strict rules regulating farmers to keep used agricultural plastic clean and dry enough for collection, as recycling collection services will refuse to take their agricultural plastic waste if the waste is too contaminated. On the other hand, farmers complain about the collectors' management systems for collected plastic and they have noticed that some recycling collectors fail to keep the collected agricultural plastic waste clean and shift the blame to the dairy farmers.

When they recycle, they only take clean plastic, you could not have dirty in it, you could not have netting in it ... but you need to be aware that farming is not a clean business ... it gets muddy; the recycler expects it as clean as they came up ... a company needs to deal with that. That would make farmers likely to sign up the scheme; collectors are like, I am not taking that, not taking that ... then you leave the responsibility to one person. (Farmer 7, male, Somerset)

DISCUSSION

The aim of this study was to understand current agricultural plastic waste management behaviours and identify the challenges involved in reducing plastic waste on British farms through the lens of the circular economy. The research in this paper used dairy farming as an example of this by conducting semi-structured online and phone interviews with 12 British dairy farmers from England and Wales. The study explored the British dairy farmers' attitudes towards the circular economy, with a focus on the application of the mantra of 'reduce, reuse, recycle' to minimise the amount of plastic used for silage production on British dairy farms. Through a thematic analysis, this study identifies the measures that British dairy farmers have taken to reduce the usage of plastic for silage production, as well as the barriers that farmers face in improving the reusing and recycling rates of plastic on their farms.

The dairy farmers in this study stated that they engage more in the clamping of silage than in the baling of silage to reduce their use of plastic. Such behaviours not only meet the feeding needs of farms with large herd sizes but have also been proven to be economically and environmentally friendly. For instance, the clamping of silage is cheaper and can be used to store more silage per acre than baled or bagged silage while using less plastic, thereby generating less plastic waste. However, the dairy farmers also pointed out that it is impossible to stop baling silage as this is more manageable than clamped silage on small and large dairy farms alike due to the bales' smaller size and lighter weight and the ability to provide a greater variety of forage.^{20,39} Hence, dairy farmers do not plan to stop making baled silage, despite the fact that it could reduce the use of plastic films. As Farmer 7 (male, Somerset) noted: '[the] environment is important, but you need to be aware that farming is business...'. In fact, such a statement is easy to understand, as consumers are found active in purchasing plastic bags out of convenience, despite there being an extra charge for the plastic bag and their awareness of the positive environmental effect of reducing the use of plastic bags.⁴⁰ For dairy farmers who seek production methods that are both cost-effective and efficient, the convenience of making and using baled silage is more important than the cost of plastic films, and the same issue also applies to their attitude towards reusing plastics.

Three of the twelve dairy farmers emphasised the effort and environmental friendliness involved in reusing sheeting plastic to reduce their overall use of plastic. However, they also pointed out the barriers for the extension of such behaviours. For instance, some farmers expressed concern about the extra financial cost of purchasing more durable and thicker sheeting plastic; furthermore, collecting, cleaning and storing the used sheeting plastic were laborious and require sufficient space.⁴¹ As Barr⁴¹ notes, people who carry out such behaviours need to have strong motivations. In addition, Farmer 12 (male, Derbyshire) pointed out that '[a] lot of British dairy farmers are thrift[y]; they [dairy farmers] cannot plan too far'. Meanwhile, compared to reuse, the dairy farmers stated that they prefer to follow normative behaviour with regard to recycling, for which more information is available and waste collectors are accessible. The majority of dairy farmers' unawareness of how to reuse plastic could be because of their insufficient reuse knowledge, as reuse behaviour has not received as much attention as reducing and recycling; refilling and reuse schemes have only been discussed in recent years, due to their use as a measure to reduce plastic packaging in supermarkets.⁴²

Although the dairy farmers expressed a high level of interest in and enthusiasm for contributing to the recycling of agricultural plastic waste on their farms, several barriers prevented them from

doing so. On the one hand, all the dairy farmers complained of not receiving sufficient help or instructions from policymakers, as local government placed more emphasis on municipal plastic waste than agricultural plastic waste. Despite this, the farmers indicated that they were happy to pay extra fees to hire recycling collectors rather than burning, landfilling or exporting their farming plastic waste. However, the everchanging agricultural plastic waste collection schemes, the insufficient provision of agricultural plastic waste collection facilities and increasing collection fees and levies all made it difficult for them to continue recycling. In addition, the dairy farmers expressed their dissatisfaction with the inequalities in the implementation of agricultural plastic management regulations, noting that they felt it was unfair that they should pay extra fees to have their plastic waste collected when they knew people who burned plastic on their farms and were not penalised.

Based on the research findings, policymakers and industry can help British dairy farmers to contribute to the circular economy and follow the mantra of reduce, reuse and recycle from the following perspectives. The first is the provision of environmental education and the promulgation of regulation among farmers. The study of Muise *et al.*⁴³ found that, after years of environmental information dissemination and education, Canadian farmers are willing to pay to recycle their waste plastic, which is a measure they refused in the 1990s. The same phenomena were identified in the UK, as the dairy farmers indicated that the TV documentary *Blue Planet* made them more aware of the importance of managing their plastic waste, and that they would pay additional fees to have their plastic waste collected and recycled. The second perspective is the improvement of agricultural plastic waste collection services and recycling facilities. The UK lacks recycling facilities especially recycling plants that can handle agricultural plastic waste.^{44,45} Studies have found that a lack of plastic collection and recycling can increase farmers' proclivity to bury, burn or dump their plastic waste.^{45,46} Therefore, it is not a surprise when the Environmental Agency identified illegal agricultural plastic waste management behaviour such as burning is still prevalent.^{26–28} The final perspective is the promotion of science–agriculture cooperation.⁴⁷ The inclusion of farmers in scientific research can help both scientists and farmers to develop a deeper understanding of agri-environmental internalities and externalities, which can help uncover additional ways to integrate environmental and economic sustainability into agricultural operations.

Although this study's findings helped to answer all the initial research questions, some limitations of the study remain. For instance, there was a limited number of participants. Both the participant-recruitment and data-collection methods were interrupted due to the COVID pandemic lockdown in the UK, as British dairy farmers expressed less interest in participating in environment-related research while handling the uncertainties imposed by the pandemic lockdown. Furthermore, this study was performed in the UK, among farmers in England and Wales; therefore, the issues raised may not be relevant for other regions. Consequently, the international transferability of the results may be influenced by the sociodemographic and cultural differences between nations. Therefore, further research should include more participants and focus on different regions or nations.

CONCLUSIONS

This study found that British dairy farmers are aware of the agricultural plastic waste problems on their farms and already followed the mantra of reduce, reuse and recycle to minimise

waste plastic on their dairy farms. However, due to the lack of material options, dairy farmers do not think they could stop using non-packaging plastic for silage production. As Bernardes¹³ asserts, there is presently no alternative to using plastic to cover bunkers or stacks that has proven successful and economically feasible for silage production. Meanwhile, extra labour and space costs to collect, clean and store used plastic, together with the unpredictable weather lower dairy farmers' willingness to reuse non-packaging agricultural plastics. Finally, the in-depth interviews with the British dairy farmers also indicate that despite British dairy farmers' interest in contributing to recycling schemes, a lack of recycling collection services for dairy farms prevents them from improving the recycling rate of non-packaging agricultural plastic waste on their farms.

British dairy farmers' positive attitudes towards adhering to the mantra 'reduce, reuse, recycle' to minimise waste plastic on farms reflects the importance of exchanging information with farmers rather than requesting farmers to change their behaviours immediately according to scientific findings.⁴⁷ As Blackstock *et al.*⁴⁷ noted, science research is one of many perspectives that can be applied to solving problems in the farming sector and there are always discussions amongst farmers of the credibility of scientific advice. Although farmers value scientific discoveries, their information consumption system has shifted from supply-driven to demand-driven, as farmers are more willing to seek out the answers to their problems rather than being told to change their behaviours blindly due to scientific findings.⁴⁸ The dissemination of scientific information should therefore shift from the unilateral transfer of knowledge from scientists to farmers to a mutual exchange of knowledge.

ACKNOWLEDGEMENTS

This research formed part of a wider project at the University of Sheffield funded by the EPSRC (EP/S025278/1). The author would like to express great thanks to all the participants, Dr Richard Bruce, Professor Lorraine Maltby and Dr Chantelle Wood for their valuable support during the research, and her thanks also go to Fiona Tovey for sharing the information from the Environmental Agency England.

SUPPORTING INFORMATION

Supporting information may be found in the online version of this article.

REFERENCES

- 1 Browne G, *Why Food's Plastic Problem is Bigger Than We Realise*. Available: <https://www.bbc.com/future/bspoke/follow-the-food/why-foods-plastic-problem-is-bigger-than-we-realise.html> [27 December 2020].
- 2 Plastics Europe. *Plastics: The Facts 2019. An Analysis of European Plastics Production, Demand and Waste Data*. Available: <https://plasticseurope.org/wp-content/uploads/2021/10/2019-Plastics-the-facts.pdf> [19 June 2020].
- 3 Hann S, Fletcher E, Molteno S, Sherrington C, Elliott L, Kong M-a, Koite A, Sastre S, and Martinez V, *Relevance of Conventional and Biodegradable Plastics in Agriculture. Final Report*. Available: <https://ec.europa.eu/environment/system/files/2021-09/Agricultural%20Plastics%20Final%20Report.pdf> [4 December 2021].
- 4 LeMoine B, Ealinna L, Trovati G, Casallo MI, Amate JJ, Ziatar K, Butlewski K, Ojanpera M, and Picuno P, *Reducing the Plastic Footprint of Agriculture*. Available: <https://ec.europa.eu/eip/agriculture/sites/>

- default/files/eip-agri_fg_plastic_footprint_minipaper_b_final.pdf [19 June 2021].
- 5 Sintim HY and Flury M, *Environ Sci Technol* **51**:1068–1069 (2017).
 - 6 Vox G, Loisi RV, Blanco I, Scarascia M and Schettini E, *Agric Agric Sci Procedia* **8**:583–591 (2016).
 - 7 Borreani G and Tabacco E, *J Dairy Sci* **98**:386–394 (2015).
 - 8 Agricultural Plastic Environment UK. Plastics in agriculture. Presented at *Sustainable Use of Plastics in Agriculture: Challenges and Solutions*, Sheffield, UK (2020).
 - 9 Uberoi E, *UK Dairy Industry Statistics*. House of Commons Library. Available: <https://researchbriefings.files.parliament.uk/documents/SN02721/SN02721.pdf> [19 October 2021].
 - 10 March MD, Haskell MJ, Chagunda MGG, Langford FM and Roberts DJ, *J Dairy Sci* **97**:7985–7994 (2004).
 - 11 Shortall OK and Lorenzo-Arribas A, *PLoS One* **17**:e0262268 (2022). <https://doi.org/10.1371/journal.pone.0262268>.
 - 12 Grant RJ and Ferraretto LF, *J Dairy Sci* **101**:4111–4121 (2018).
 - 13 Bernardes TF, *Advances in Silage Sealing*. Available: <https://www.intechopen.com/books/advances-in-silage-production-and-utilization/advances-in-silage-sealing> [19 June 2020].
 - 14 AHDB, *Making Grass Silage for Better Returns*. Available: <http://beefandlamb.ahdb.org.uk/wp-content/uploads/2018/06/Making-grass-silage-for-better-returns.pdf> [16 June 2020].
 - 15 Agriculture and Food Development Authority, 2016, *Quality Grass Silage for Dairy and Beef Production Systems, A Best Practice Guide*. Available: <http://beefandlamb.ahdb.org.uk/wp-content/uploads/2018/06/Making-grass-silage-for-better-returns.pdf> [16 June 2020].
 - 16 Moran J, Making quality silage, in *Tropical Dairy Farming: Feeding Management for Small Holder Dairy Farmers in the Humid Tropics*. Landlinks Press, Collingwood, pp. 83–97 (2005).
 - 17 Jennings J and Coffey K, *Baled Silage for Livestock*. Available: <https://www.uaex.uada.edu/publications/pdf/FSA-3051.pdf> [19 July 2020].
 - 18 Rogers GL, Bryant AM, Jury KE and Hutton JB, *N Z J Agric Res* **22**:511–522 (1979).
 - 19 Coblenz WK and Akin MS, *J Dairy Sci* **101**:4075–4092 (2014).
 - 20 Borreani G, Tabacco E, Schmidt RJ, Holmes BJ and Muck RE, *J Dairy Sci* **101**:3952–3979 (2018).
 - 21 Borreani G, Tabacco E and Cavallarin L, *J Dairy Sci* **90**:4701–4706 (2007).
 - 22 Briassoulis D, Babou E, Hiskakis M, Scarascia G, Picuno P, Guarde D *et al.*, *Waste Manag Res* **31**:1262–1278 (2013).
 - 23 Steinmetz Z, Wollmann C, Schaefer M, Buchmann C, David J, Troger J *et al.*, *Sci Total Environ* **550**:690–705 (2016).
 - 24 Mihai FC, Gundogdu S, Markley LA, Olivelli A, Khan FR, Gwinnett C *et al.*, *Sustainability* **14**:20 (2022). <https://doi.org/10.3390/su14010020>.
 - 25 Gionfra S, *Plastic Pollution in Soil*. Available: <https://ieep.eu/uploads/articles/attachments/3a12ecc3-7d09-4e41-b67c-b8350b5ae619/Plastic%20pollution%20in%20soil.pdf?v=63695425214> [27 June 2020].
 - 26 Environment Agency, *Environmental Good Practice Guide for the Collection of Non-Packaging Plastics*. Available: https://www.wrap.org.uk/sites/files/wrap/Good_Practice_Guide_for_non-packaging_plastics_cc7_6943.pdf [27 June 2020].
 - 27 Tovey F, *Why Plastics Used on Farms is Worth Talking About*. Available: <https://environmentagency.blog.gov.uk/2020/11/27/why-plastics-used-on-farms-is-worth-talking-about/> [27 December 2020].
 - 28 Environment Agency. *Towards Sustainable Agricultural Waste Management*. Available: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/291600/geho0003bioe-e-e.pdf [19 October 2021].
 - 29 Department for Environment, Food and Rural Affairs. *Guidance on Applying the Waste Hierarchy*. Available: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/69403/pb13530-waste-hierarchy-guidance.pdf [27 June 2020].
 - 30 Agriculture and Food Development Authority. *Quality Grass Silage for Dairy and Beef Production Systems: A Best Practice Guide*. Available: <https://www.teagasc.ie/media/website/publications/2016/Teagasc-Quality-Grass-Silage-Guide.pdf> [19 October 2021].
 - 31 Ann AG, *Med Surg (Lond)* **23**:19–23 (2019).
 - 32 Mehta N, Cunningham E, Roy D, Cathcart A, Dempster M, Berry E *et al.*, *Sustainable Prod Consumption* **26**:574–587 (2021).
 - 33 DeJonckheere M and Vaughn LM, *Fam Med Commun Health* **7**:e000057 (2019). <https://doi.org/10.1136/fmch-2018-000057>.
 - 34 Edgar TW and Manz DO, Research methods for cyber security, in *Exploratory Study*, 1st edn. Syngress, Cambridge, US, pp. 95–130 (2017).
 - 35 Braun V and Clarke V, *Qual Res Psychol* **3**:77–101 (2006).
 - 36 DEFRA. *Agricultural Labour in England and the UK Farm Structure Survey 2016*. Available: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/771494/FSS2013-labour-statsnotice-17jan19.pdf [29 June 2021].
 - 37 DEFRA. *Agriculture in the United Kingdom 2019*. Available: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/950618/AUK-2019-07jan21.pdf [29 June 2021].
 - 38 Brassley P, *Silage in Britain, 1880–1990: The Delayed Adoption of an Innovation*. Available: <https://www.bahs.org.uk/AGHR/ARTICLES/44n1a5.pdf> [27 June 2020].
 - 39 James D, *Bales Offer Cost and Flexibility Advantages*. Available: <https://www.fwi.co.uk/livestock/bales-offer-cost-and-flexibility-advantages> [27 June 2020].
 - 40 Muhlthaler T, Rademacher L. *uwf25*:189–202 (2017).
 - 41 Barr S, *Environ Behav* **39**:435–473 (2007).
 - 42 Jackson M. *Plastic Packaging: How Are Supermarkets Doing?* Available: <https://www.bbc.co.uk/news/uk-49674153> [27 June 2020].
 - 43 Muise I, Adams M, Cote R and Price GW, *Resour Conserv Recycl* **109**:137–145 (2016).
 - 44 Corna NL, Krause S, Lych I. *Getting a Grip of the UK's Plastic Recycling Crisis: Alternatives to Shipping the Problems Overseas*. Available: <https://www.birmingham.ac.uk/news/2021/getting-a-grip-on-the-uks-plastic-recycling-crisis-alternatives-to-shipping-the-problem-overseas> [27 June 2020].
 - 45 BBC News. *Farmers Consider 'Burning or Burying' Plastic Waste*. Available: <https://www.bbc.co.uk/news/uk-wales-48246060> [27 June 2020].
 - 46 Wen ZG, Xie YL, Chen MH and Dinga CD, *Nat Commun* **12**:425 (2021). <https://doi.org/10.1038/s41467-020-20741-9>.
 - 47 Blackstock KL, Ingram J, Burton R, Brown KM and Slee B, *Sci Total Environ* **408**:5631–5638 (2010).
 - 48 Garforth C, Angell B, Archer J, Green K, *Improving Farmers' Access to Advice on Land Management: Lessons from Case Studies in Developed Countries*. Available: <https://citeserx.ist.psu.edu/viewdoc/download?doi=10.1.1.203.1977&rep=rep1&type=pdf> [12 July 2020].