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AN INVESTIGATION OF THE EFFECTS OF INTRODUCING AN ALTERNATIVE CATTLE FEEDING METHOD ON A DAIRY FARM

George HARGREAVES[1], Adam ECKERSLEY[1], Philip BOYLE[1], Lancelot BUTTERS[2]

[1]Myerscough College, Bilsborrow, Preston PR3 0RY, United Kingdom
[2]University of Central Lancashire, Preston, Lancashire, PR1 2HE, United Kingdom

Corresponding author email: ghargreaves@myerscough.ac.uk

Abstract

With the cost of farm labour in the UK remaining stable through 2020 and the cost of milk rising Reeve (2021) (AHDB, 2022), there is an increasing incentive to capitalise on these unique circumstances. Dairy farms have recognised for years, the vitality of providing the correct sustenance to cattle. It is recognised that correct levels of feed supplied to the cattle has an impact on milk yield. Another factor to consider, when it comes to feed, is the quality of the mix that is produced from a diet feeder. With diesel prices continuing rise, a more fuel efficient alternative to traditional feeding is being sought, without sacrificing quality. This report investigates the financial effects recorded when implementing a self-propelled diet feeder into a 146 cow dairy farm in Lancashire. Using primary research, gathered from a series of tests, carried out between a self-propelled diet feeder and the conventional trailed machine. The results showed the benefits of the self-propelled machine outweighed the negative aspects. Due to the study only being carried out on a single farm the data cannot represent other farms. However, on this farm, the increased value of milk yield exceeded the additional cost of diesel fuel used and time taken by the self-propelled unit. As a conclusion an increased daily income of £61.10, when using the self-propelled, it would take a projected nine years to pay off the machine with current labour, diesel and milk prices.

Key words*: farm labour, milk production, self-propelled, diet feeder Lancashire.*

INTRODUCTION

Design briefs in the agricultural engineering industry feature two main words: productivity and efficiency (Careers, 2022). Productivity is measured by the level of input vs the level of output from a certain operation (Krugman, 1990). These inputs could be quantified as labour, economic input or materials for example (Milano, 2019). An increase in productivity is notable when a company or manufacturer increases its outputs while maintaining the same level of inputs (Bjorkman, 1992). Meanwhile, efficiency is defined as producing as little to no waste when aiming to achieve an end goal or product (Dincer, 2018). In other words, productivity relates to the quantity of goods produced, while efficiency is the amount of materials used to produce that work (Hemphill, 2018). Companies which can strike a balance between the two fundamentals are able to offer a product that will bring the end consumer profitability in both working time and the materials used in the production of the end product (Fried, 1993).

The aspect of efficiency vs productivity can be applied to more or less any industry (Coelli, 2005). The agriculture and agricultural engineering industry has many different areas that could be analysed in relation to efficiency and productivity. Over the past 100 years, the world's population has quadrupled (Roser, 2019). In order to maintain the necessary outputs required from the agricultural sector, the industry has had to adapt and evolve to meet increased demand (Almond, 2021). These adaptations have had to allow organisations and businesses to increase output with the same input while also maintaining economic viability by limiting waste (Ghebremichael, 2013). One way of analysing whether or not an agricultural business is viable is by completing studies into the efficiency and productivity of a certain area (Oum, 1999). With the agricultural sector looking to increase outputs, maintain inputs and reduce waste, both efficiency and productivity are vital to reaching this goal (Latruffe, 2012).

This study will focus on the cattle production sector for dairy and beef. Within this area, there are many different inputs and outputs that can be

analysed. However, the feeding of cattle is the highest input on the farm (in terms of capital invested) (Halladay, 2018). Therefore, if there is a change in either productivity or efficiency in this area, there will be a direct effect on the bottom line, whether that be positive or negative. It will also analyse the effects that altering feeding practices on a case study farm will have on a range of inputs and outputs, plus examine any changes in efficiency and productivity. In addition it will analyse the effects that such an alteration has on every aspect of the dairy-production process, from feeding through to milk yield. The alteration on the farm in question is the implementation of a self-propelled diet feeder when compared to the traditional trailed diet feeder used previously.

The farm in question has a 146 average head of dairy cattle along with 90 head of beef cattle, 53 head of heifers and 25 dry cows. The data collected will investigate diesel use between the two methods of feeding, the difference in milk yield in the dairy cows and the overall time taken to feed up.

MATERIALS AND METHODS

There are three main areas of concern that must be focused upon during data collection. These areas are reliability, validity and generalisability. The best way to improve reliability is through explanation of the methods used during a research project (Swetnam, 2009). The main question of reliability is, would the same procedures carried out again yield the same results? One way of increasing reliability is by ensuring that procedures and tactics are both followed and well documented. By following rigorous standards, this also ensures that validity is sufficient. Validity relates to the accuracy of the means of measurements (Bell, 2014); accurate means of measuring ensure that the results gained are valid to the highest level of reliance. The means of measuring also need to be able to bear the weight of the results or the claims made, otherwise the project would be open to valid criticism. Generalisability relates to the relevance of the research in question to the wider industry (Briesch, 2014). All of the points below address how this study will approach each factor stated above.

The use of primary data has many advantages over using secondary data, one of which is the authenticity of the results gained (Formplus, 2021). While secondary data is vital in research projects in which the option to gather primary data is not available, the gathering and analysing of primary data is often seen as more reliable. For example, when using secondary data from manufacturer studies, the data could be biased towards their product. This would be beneficial to a manufacturer, as inflated savings and data could make a product more appealing to the consumer. Ana Dolores Franco Valdez (2018) states that exaggerated or inflated product claims directly affect consumer evaluations of a company. Along with Ms Valdez, the Elaboration Likelihood Model (ELM) developed by Richard E. Petty and John T. Cacioppo (Petty, 1986) states that even strong claims from a manufacturer or company will have a profound effect on a consumer's ideologies of a company. Therefore the use of primary data (in research projects) both validates claims by companies and manufacturers while also providing useful information to prospective consumers from an unbiased point of view.

Due to the nature of this study, however, results will be obtained entirely from primary data that has been collected down at the dairy and beef units of Myerscough Farms (more specifically Lodge Farm). The first method of data collection used was a series of tests carried out between two separate machines. The two machines in question are a self-propelled Keenan MechFibre 345SP (known in this study as SP) and a Keenan MechFibre 365 (Known is this study as TM). The key difference between the two machines is that the MechFibre 345SP is a 2017 self-propelled unit fitted with a milling head which feeds certain raw materials into the tub, while the MechFibre 365 is a trailed unit which requires a telescopic handler or a loader tractor in order to put certain materials into the tub, as well as a power unit on the diet mixer itself. The associated tractor that powered the MechFibre 365 was a 2017 McCormick X6.430 and the associated telescopic handler unit used, a 2021 Kramer KT 357.

Figure 1. Trailed feeder wagon with the associated tractor and telescopic handler unit

Figure 2. Self-propelled feeder wagon used in this study

One of the first and more obvious advantages of using a self-propelled machine as opposed to the conventional trailed method is that the operation of loading and mixing is executed by a single machine. From a machinery point of view, in theory, this should limit the maintenance and diesel requirements. However, to verify these claims. Diesel consumption tests were carried out on both the self-propelled feed mixer and trailed feed mixer. These tests were carried out between 14/02/2022 and 04/03/2022. This time frame allowed 8 days of tests for each diet feeder while also allowing for a contingency, of a few days, in case of any situations in which testing would not be possible. The feeding structure at Lodge consists of five feed mixes spread across a circuit of two days. For example, day one would consist of a beef feed mix and then a high milking mix and a low milking mix, and day two would consist of the high and low milking mixes as well as a heifer and a dry cow mix. This structure means that the beef, heifer and dry cows are fed once every other day while the milking cows (known in this study as PD Plus (low milking) and open cow (high milking)) are fed once every day. Due to the eight-day testing period, this would therefore result in eight PD plus and open cow mix diesel consumption results for both the self-propelled and the trailed feeder wagon, as well as four sets of results for beef, heifer and dry cows for both feed mixing methods. As the most frequent source of income on the farm comes from the sale of milk, the feeding and therefore the yield of milk was under the closest scrutiny. The higher number of milking mix results that were gathered then facilitated a higher level of analysis, which could then be directly compared to any differences in milk yield.

The diesel consumption tests were carried out firstly on the self-propelled machine then on the trailed machine in blocks of eight days. These tests were carried out using one-litre measuring cylinders that were accurate to +/- 10 cm^3 or 10 millilitres. Two five litre and one two litre jugs were used throughout the tests to streamline the process and therefore prevent excess disruption to the feeding schedule. The five and two-litre jugs were filled between feeds using the one-litre measuring cylinder. This tactic was adopted after a series of four trial tests, as it was seen to greatly reduce the time taken to refill the machine after each test and would therefore create the least amount of disruption while maintaining the maximum level of accuracy. Prior to each day's feeding schedule the machine was filled to the specified level, which, on all machines in these tests, was just as the filler neck on the diesel tank widened out to the main tank. Once filled, the machine would then complete its usual gathering, mixing and dispensing of feed to the specified group of cattle. Once the whole feeding process was complete, the machine would then return to the yard and the engine would be switched off. At this point, the tank would be filled back to the specified fill point and the process would then repeat between three and four times a day. The level of diesel left in either the two-litre jug, five-litre jug or one-litre measuring cylinder was then measured, and the total combined diesel for the self-propelled was recorded. During the trailed diesel tests the same principles were adopted, however the diesel use for the telescopic handler and the tractor were measured individually.

Another area for investigation, on a dairy farm, is the time taken to complete tasks (Jackson, 2009). To accurately assess this area, which the self-propelled mixer claims to improve, the time was noted when the engine was started at the

beginning of every feed mix and when the engine was stopped at the end of every feed mix. This would give a better understanding of the length of time taken to complete each feed cycle individually recorded, with a tolerance of +/- 59 seconds. As per the diesel consumption tests, the time was recorded from engine start to engine cut off for both the telescopic handler and the tractor separately. This allowed for comparison between time taken and diesel consumption on a litres-per-hour basis.

One area for consideration when carrying out the diesel consumption and time tests was the mix percent that was being made up. The mix percent relates to how much of the TMR is being made. For example, if the cattle only consumed 90% of the previous mix, the mix percent would be lowered to 90%. This changing of percentage mix would ensure that there was minimal waste between mixes and that 100% of what was being mixed would be consumed by the cattle. This changing of mix percent would directly affect the diesel and time taken tests as the higher the mix percentage then the higher the load on the machine and theoretically the higher the rate of diesel consumption.

The final method of data collection in this project is through a fully-structured interview. This interview was carried out with a member of staff who currently works on the farm. The participant is work based but also carries out managerial duties. Due to the comparative nature of this thesis, a structured interview was selected, as this means the results are more easily compared to one another (Horton, 2004). In the case of this research project, a structured interview was also beneficial as questions could be pre-planned while the test was taking place. This was more common where there were operation-based questions. The interviewee was selected due to them occupying the most job roles on the farm, and this may cause there to be differences in answers given based on what benefits and drawbacks directly affect the individuals as either operators or managers. The initial method would to have been to interview several of the farm staff, however due to time constraints and working commitments, only one member of staff was available to be interviewed. Finally, through working with farm management, access was granted to milk yield data and feed ingredient data, which will also be used in this study.

RESULTS AND DISCUSSIONS

The results of the tests from this research project have allowed a multitude of different angles to be assessed. These findings have allowed operators to be compared in terms of diesel use and time taken. However, due to the logistics of the farm, the same frequency of operators was not available for the second set of tests on the trailed feeder wagon. Therefore, new operators as well as operators from the first set of tests featured in the second set of tests as is seen from the data below. As well as operator comparison, the findings have also allowed analysis of which mixes tend to use the most and least amounts of diesel. As a whole, the results have allowed large-scale comparison between the two types of feeder wagons as shown on the following pages. These results show clear trends between the two diet feeders, however further analysis is needed in order to define which diet feeder is preferable in terms of pricing. The farm worker referred to in the main text as Patrick appears as Pat in tables and interviews.

Table 1. Data sheet for the diesel tests for the self-propelled feeder wagon (14-21/02/2022)

	Test Number	Date and time	Diesel used (litres)	Operator	Type of feed	Time Taken
SP feeder wagon	1	14/02/20	10.31	Pat	Dry	49
	2	14/02/20	4.9	Pat	PD Plus	31
	3	14/02/20	6.46	Pat	Open Co	45
	4	15/02/20	8.96	Pat	Heifer M	42
	5	15/02/20	4.82	Pat	Beef Mix	20
	6	15/02/20	2.13	Pat	PD Plus	27
	7	15/02/20	9.42	Pat	Open Co	45
	8	16/02/20	4.77	Ben	Open Co	29
	9	16/02/20	7.67	Ben	PD Plus	40
	10	16/02/20	7.94	Ben	Dry	56
	11	17/02/20	11.75	Pat	PD Plus	37
	12	17/02/20	5	Pat	Open Co	31
	13	17/02/20	3.845	Pat	Beef Mix	19
	14	17/02/20	6.6	Pat	Heifer M	29
	15	18/02/20	7.46	Ben	Dry	40
	16	18/02/20	6.45	Ben	PD Plus	39
	17	18/02/20	6.605	Ben	Open Co	38
	18	19/02/20	7.85	Ben	PD Plus	27
	19	19/02/20	4.015	Ben	Heifer M	23
	20	19/02/20	2.925	Ben	Beef Mix	13
	21	19/02/20	8.18	Ben	Open Co	43
	22	20/02/20	6.91	Pat	PD Plus	38
	23	20/02/20	5	Ben	Dry	28
	24	20/02/20	5	Ben	Open Co	34
	25	21/02/20	11.76	Pat	Heifer M	44
	26	21/02/20	3.955	Pat	Beef Mix	16
	27	21/02/20	4.6	Pat	PD Plus	38
	28	21/02/20	6.86	Pat	Open Co	56

Table 2. Data sheet for the trailed diet feeder wagon

	Date and time	Tractor diesel use	Kramer diesel used	Type of feed	Total diesel used	Time taken
Trailed feeder wa	24/02/2022 1:24pm	5.29	2.3	Heifer	7.585	51
	24/02/2022 2:16pm	2.16	1.14	Dry Cow	3.3	44
	24/02/2022 3:02pm	1.91	1.31	PD Plus	3.22	24
	24/02/2022 3:31pm	2.53	1.48	Open Cow	4.005	43
	25/02/2022 2:05pm	3.75	0.77	Beef Mix	4.52	20
	25/02/2022 2:32pm	1.85	1.04	PD Plus	2.89	44
	25/02/2022 3:18pm	3.4	1.27	Open Cow	4.67	52
	26/02/2022 5:29am	7.34	2.96	Dry Cow	10.3	48
	26/02/2022 6:21am	1.39	1.51	Heifer	2.9	21
	26/02/2022 6:43am	4.32	1.89	Open Cow	6.21	29
	26/02/2022 7:17am	1.67	1.5	PD Plus	3.165	26
	27/02/2022 2:10pm	3.23	0.91	Beef Mix	4.135	21
	27/02/2022 2:34pm	1.61	1.01	PD Plus	2.615	24
	27/02/2022 3:03pm	1.72	1.34	Open Cow	3.06	50
	28/02/2022 2:18pm	6.86	1.68	Heifer	8.54	35
	28/02/2022 2:55pm	1.62	1.08	PD Plus	2.7	27
	28/02/2022 3:22pm	2.34	1.65	Open Cow	3.99	40
	28/02/2022 4:04pm	2.97	1.47	Dry Cow	4.435	41
	01/03/2022 3:10pm	8	1.51	PD Plus	9.51	33
	01/03/2022 3:47pm	2.58	1.73	Open Cow	4.31	40
	01/03/2022 4:29pm	3	0.87	Beef Mix	3.87	16
	03/03/2022 1:09pm	3.72	1.2	Beef Mix	4.92	33
	03/03/2022 1:42pm	3	1.13	PD Plus	4.13	29
	03/03/2022 2:23pm	2.16	2	Open Cow	4.16	41
	04/03/2022 11:23am	5.55	1.44	Open Cow	6.99	35
	04/03/2022 12:03pm	2.2	1.15	Dry Cow	3.35	24
	04/03/2022 12:32pm	1.58	1.01	Heifer	2.59	19
	04/03/2022 3:33pm	2.13	2.18	PD Plus	4.31	35

This table shows the data collected during the trailed feeder wagon and telescopic handler tests. All the data and tables and figures are the result of data gathered during diesel tests. Finally, milk yield data collected from the farm will be used as a reference point to assess change between feed wagons.

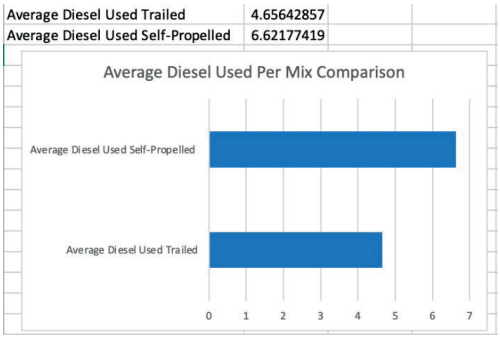

Figure 3. The average diesel used per mix for both the self-propelled diet feeder and the trailed diet feeder

The data shows that the trailed feeder used 1.96 litres less per mix, on average, than the self-propelled diet feeder.

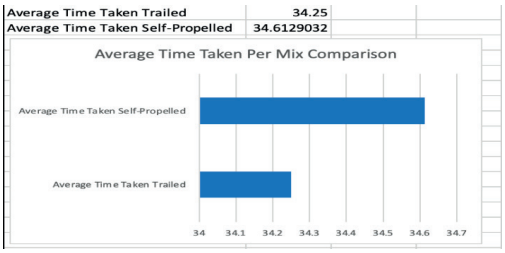

Figure 4. The average time taken per mix for both the self-propelled diet feeder and the trailed diet feeder

From the data and the graph it is clear that the self-propelled took an average of 22 seconds longer.

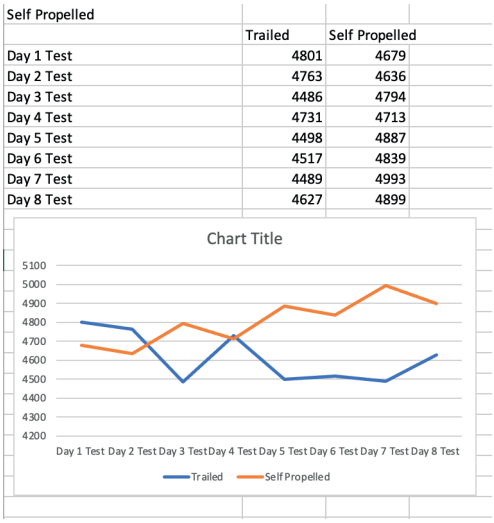

Figure 5. The changes in milk yield during the times of testing

The results appear to be sporadic and don't show a clear trend. However, it must be taken into account that the first 2 days with the trailed feeder shows the time where the cattle were likely still benefiting from the quality of feed mix provided by the self-propelled unit.

In the primary stages of this project, the initial hypothesis was that due to the self-propelled occupying the role of two machines, the diesel use would be lower. In addition to this, due to the self-propelled constantly mixing, this means that static mixing is not required once all materials are loaded into the diet feeder. It was expected that the self-propelled mixer would complete feeding in a more timely fashion than the trailed alternative. From the data it is clear that the

original hypothesis was incorrect however, as predicted there was an increase in milk yield.
When it comes to justifying the purchase of a self-propelled diet feeder on any farm, there are a number of different factors that need to be assessed and analysed before a decision can be made. The most pertinent of these factors are as follows.

Purchase Price

With a base model Keenan self-propelled on the market for £169,000 (Mowbray, 2017) and a trailed unit costing roughly £50,000 (French, 2022), there is a minimum capital sum of £119,000 to be put forward in order to equip a farm with a self-propelled diet feeder as opposed to a trailed diet feeder. The bulk of this transaction will come from the power train that the self-propelled unit is fitted with. However, with a trailed diet feeder the required elements - tractor and telescopic handler or loader tractor - are already commonplace on farms up and down the country. In the interview with Patrick, he shared the same view as Mowbray, saying that the upfront cost of switching to a self-propelled diet feeder would be a stumbling block for smaller dairy units with less throughput.

Diesel use

When any consumer in any industry purchases a piece of machinery with a fuel intake, one key factor that will be taken into consideration will be the efficiency of that fuel intake. Therefore, one point that manufacturer, Keenan, was claiming is a fuel consumption reduction of up to 25% (Keenan, 2021). However, the data in this study has shown that the average fuel consumption for the self-propelled diet feeder at Myerscough Farms was 1.97 litres more per mix (Figure 6) than the conventional trailed method. This is an increase of 42.2% per mix average. However, one of the main discussion points, with regards to the trailed unit, is the change in practices since the implementation of the self-propelled diet feeder. As stated by Patrick in his interview, the milling of the straw by the self-propelled feeder is very high quality, whereas with the trailed unit the straw isn't processed nearly as well. Prior to the self-propelled mixer, the farm used to rely on the trailed unit and pre-chopped the straw through a straw chopper before entering it into the diet feeder. The claimed fuel consumption from the trailed mixer, therefore, does not incorporate the fuel that used operating the pre-chopper. The pre-chopping of the straw would add an increase to the diesel fuel consumption using the trailed unit.

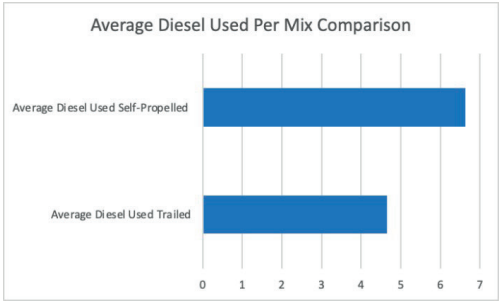

Figure 6. Comparison of the average diesel used per mix

This shows that the self-propelled feeder wagon used more fuel, when the average was calculated, compared to the trailed feeder wagon and telescopic handler (Figure 7).

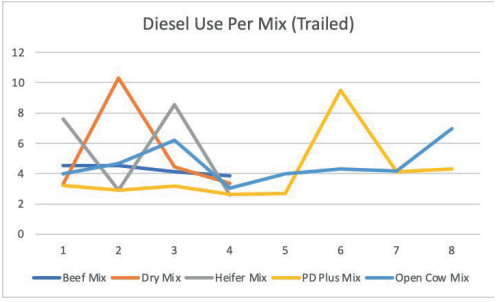

Figure 7. Diesel use per mix for the trailed machine

There are clearly four main anomalies in the data, these occur on day 1 with the heifer mix, day 2 with the dry mix, day 3 with the heifer mix and day 6 with the PD Plus mix.

Table 3. Type of feed

	Date and time	Tractor diesel use	Kramer diesel used	Type of feed	Total diesel used	Time taken
Trailed feeder wa	24/02/2022 1:24pm	5.29	2.3	Heifer	7.585	51
	24/02/2022 2:16pm	2.16	1.14	Dry Cow	3.3	44
	24/02/2022 3:02pm	1.91	1.31	PD Plus	3.22	24
	24/02/2022 3:31pm	2.53	1.48	Open Cow	4.005	43
	25/02/2022 2:05pm	3.75	0.77	Beef Mix	4.52	20
	25/02/2022 2:32pm	1.85	1.04	PD Plus	2.89	44
	25/02/2022 3:18pm	3.4	1.27	Open Cow	4.67	52
	26/02/2022 5:29am	7.34	2.96	Dry Cow	10.3	48
	26/02/2022 6:21am	1.39	1.51	Heifer	2.9	21
	26/02/2022 6:43am	4.32	1.89	Open Cow	6.21	29
	26/02/2022 7:17am	1.67	1.5	PD Plus	3.165	26
	27/02/2022 2:10pm	3.23	0.91	Beef Mix	4.135	21
	27/02/2022 2:34pm	1.61	1.01	PD Plus	2.615	24
	27/02/2022 3:03pm	1.72	1.34	Open Cow	3.06	50
	28/02/2022 2:18pm	6.86	1.68	Heifer	8.54	35
	28/02/2022 2:55pm	1.62	1.08	PD Plus	2.7	27
	28/02/2022 3:22pm	2.34	1.65	Open Cow	3.99	40
	28/02/2022 4:04pm	2.97	1.47	Dry Cow	4.435	41
	01/03/2022 3:10pm	8	1.51	PD Plus	9.51	33
	01/03/2022 3:47pm	2.58	1.73	Open Cow	4.31	40
	01/03/2022 4:29pm	3	0.87	Beef Mix	3.87	16
	03/03/2022 1:09pm	3.72	1.2	Beef Mix	4.92	33
	03/03/2022 1:42pm	3	1.13	PD Plus	4.13	29
	03/03/2022 2:23pm	2.16	2	Open Cow	4.16	41
	04/03/2022 11:23am	5.55	1.44	Open Cow	6.99	35
	04/03/2022 12:03pm	2.2	1.15	Dry Cow	3.35	24
	04/03/2022 12:32pm	1.58	1.01	Heifer	2.59	19
	04/03/2022 3:33pm	2.13	2.18	PD Plus	4.31	35

One common factor regarding the dates and the anomalies is that the spikes occur on the first test of the day on the 24/02, 26/02, 28/02 and 01/03. Overnight the tractor doesn't move and isn't run, however the fuel cools down once the tractors have been topped up while still warm. One possible explanation for this apparent increase in fuel consumption is the expansion of fuel during the period of mixing feed. Then, overnight, the fuel cools/contracts and this leads to a lower fuel level in the morning compared to the day before. To tackle this problem, the machine should have been filled up prior to testing at the start of each day rather than at the end of each day to prevent incorrect data. However, a problem that would then arise would be, for example, if the machine took somewhere between four and six extra litres, where that fuel data would be accredited to. One possible solution would be to fill up the tractor once it was warm and complete all tests while the machine was warm. However, amending these results would only decrease the trailed diet feeders overall average diesel consumption. With the trailed mixer already showing that it burns less diesel, for the purpose of this investigation, the results will remain.

Milk Yield Change

One method to access the quality of the mix is to measure waste from the feed, i.e. what the cows have sorted through, and left, in the troughs and compare with the associated milk yields. In Patrick's interview he claimed that due to the self-propelled's ability to process straw to a much higher standard, "*the cows are eating the same ration all the time whereas with the trailed there are spikes where they'll pick things out of the ration that they shouldn't be able to*". This statement highlights two factors of the self-propelled where the trailed is inferior. The first of these factors is that the cows do not sort through the feed as much and are therefore eating the same volume and mix contents every day. The second factor is the consistency of the feed that is put out; with the feed out of the self-propelled being far more consistent, K.A. Beauchemin (2018) and Mohammadreza Ebrahimi (2018) claim that it is better for the cows to ingest a more even mix with the correct levels of micronutrients being spread across the whole mix rather than having concentrated patches of mix containing more vitamins. Patrick also claims that this is due to the way the diet feeder is loaded. 'With the trailed feeder you've got to fill the mixer in two halves because it doesn't transfer mix from the front to the back. Whereas with the self-propelled because it's throwing it in an arc over the tub it's dropping out all the way along so you get a much more consistent mix.' Ali Hassanpour (2011) corroborates this statement with both Patrick and Ali explaining the benefits from the conveyor from the milling head 'throwing' the material into the tub, the material is effectively placed along the full length of the tub rather than in sections like in the trailed feeder. During the tests it was clear to see that care had to be taken when loading the trailed feeder and materials such as silage and straw had to be dropped in evenly in the front and the back. When asked whether the level of refusal and wasted feed had gone up or down, Patrick claimed that, "*because the feed is a lot more consistent we throw less away*". He put the reduction in wasted feed down to the more consistent feed, meaning the cows were unable to sort through the feed and leave undesirables in the trough.

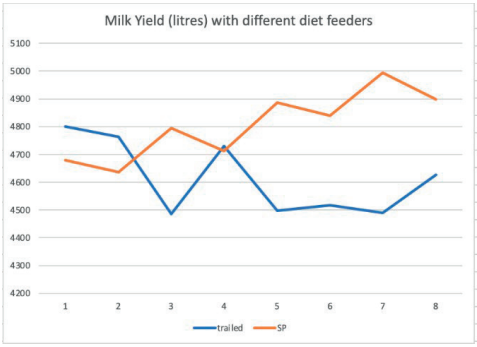

Figure 8. Milk yield comparison between the trailed diet feeders.

The milk yield changed over the course of the testing period while using both the self-propelled and the trailed feeders. It is clear, from the graph in Figure 8, that the milk yield during the trailed period is erratic. This inconsistency would corroborate Patrick's claim that the trailed mixer supplied the cows with irregular feed and therefore would bring the milk yield down or make it unstable. The plateaued, high section at the start of the trailed mixing period could be explained by the cattle still ruminating the feed from the self-propelled mixer and then, once dependant on the trailed mixer, the graph shows a general downward to resting trend around 4,500 litres with a single anomaly on day four of testing. As with the self-propelled, from the start there is a general upward trend with regular peaks.

Table 4. Typical rates of pay and costs

	Self-Propelled	Trailed
Average Hours Per Day	2.04	2
Rate of Pay	£17.96	£17.96
Average Pay Per Day	£36.64	£35.92

The average salary for a herd manager in the United Kingdom in 2022 is £17.96/hour (Talent, 2022).

Table 5. The UK cost of agricultural diesel (2022)

	Self-Propelled	Trailed
Average Diesel Burnt Per Day	22.768125	16.2975
Cost Per Litre	£1.04	£1.04
Total	£23.68	£16.95

Table 6. The UK price of milk (2022)

	Self-Propelled	Trailed
Average Litres Per Day	4805	4614
Price Per Litre	0.3589	0.3589
Total sale value per day	£1,724.51	£1,655.96

The price of milk in the UK was 35.89 pence per litre in February 2022 (AHDB, 2022).

Table 7. Comparison chart showing costs/income for the two machines

	Self-propelled	Trailed
Labour Outgoings	£36.64	£35.92
Fuel Outgoings	£23.68	£16.95
Milk Yield Income	£1,724.51	£1,655.96
Total income	£1,664.19	£1,603.09

From the table above and the previous Tables 4-7, it is clear to see that although labour and fuel costs are higher for the self-propelled, due to the increase in milk yield the self-propelled still boosts the farm's profits by £61.10 per day. Over the course of a year this equates to £22,301.50 profit from the self-propelled compared to the trailed. However, there is still the factor of the £180,000 initial purchase price to consider.

Break Even Analysis:

In order to fully understand how beneficial this machine would be, a break-even analysis must be carried out to see how long the machine would need to be implemented in order to pay itself off.

Table 8. Year-by-year income

Financial status	Year	Annual savings @ £61.10/day
	1	£22,301.50
	2	£44,603
	3	£66,904.50
	4	£89,206
	5	£111,507.50
	6	£133,809
	7	£156,110.50
	8: Base Model Pay Off Point	£178,412
	9: Current Method Pay Off Point	£200,713.50

From the Table 8 it shows that it would take nine years of operating at the same level as it did

during the tests in order to pay itself off. More specifically, it would take exactly 420.86 weeks in order to pay itself off or 2,946 days.
From the data shown, it is clear why a small farm would not be able to overcome the initial purchase cost of an item of machinery such as a self-propelled diet feeder.

CONCLUSIONS

- The break-even point when purchasing a self-propelled diet feeder, in this instance, is 9 years.
- When supplied with feed from the self-propelled diet feeder, cow milk yield rose by 4.06% when compared to the trailed diet feeder.
- The refusal rate from the cattle was significantly reduced when using the self-propelled diet feeder compared to the trailed diet feeder therefore reducing waste.
- Fuel consumption for the trailed diet feeder was 33.13% lower on average than that of the self-propelled.
- The self-propelled diet feeder took on average 0.4 hours longer per day when compared to the trailed alternative.

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