Improving feed efficiency through grazing management

BACHELOR THESIS

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Improving feed efficiency through grazing management

Bachelor thesis

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Preface

In front of you lies my bachelor thesis "Improving feed efficiency through grazing management". From my Christian background I have a strong believe that we as humanity have a duty to take care of our environment and the people living in this world. Dairy production has the potential to improve the lives of a lot of people through providing them with the healthy nutrients but is also at risk of negatively impacting the environment. By doing this research on making dairy production more efficient I tried to do my little part in making the world a better place.

The research was carried out at the farm of Brian Rushe in county Kildare. This is a modern, well performing farm and a great place to learn. Brian is always open to ideas that could make his farm perform even better and generous in sharing data needed for such research. The research was written for (Irish) dairy farmers in general, but the results are specifically useful for the use on Brian Rushe's farm. I would like to thank Brian for the great opportunity of writing my thesis and doing my final placement at his farm.

Hereby, I would also like to thank my teacher, Geronda Klop. She was always open to answer my questions and help me further when I was stuck in the writing process. I would like to thank her for her help with the statistics and the writing process of this thesis.

I hope you enjoy reading it.

Marieke Dekker

Edenderry, 6 July 2019

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Summary

The goal of this research was to find out if, and if yes, how, grazing management could be used to improve concentrate feed efficiency and thus farm income on commercial Irish dairy farms. The research was carried out on a commercial Irish dairy farm milking 240 crossbred cows on a dry farm with sandy loam soil during the second and half of the third grazing round. Data regarding feed efficiency, dry matter cover, paddock size, grass varieties, soil P and K levels and fertilizer application were gathered from available farm data. Weather data were gathered from the national meteorological institution. Because the data were gathered on only one farm, the research should be treated as a pilot study. The study is a valuable source of information on what grazing management factors could improve feed efficiency, but more research should be done to see if the same results can be achieved at different farms and over a longer period.

The research showed that grazing time per paddock, concentrate feeding level and grass variety have the potential to increase concentrate feed efficiency in a business economic efficient way. Managing grazing time per paddock could best be achieved by switching to the strip grazing system. In this way, the available grass cover can be matched exactly to the herds requirements. The cost of this system depends on the existing farm layout, but mostly consists of increased labour costs. More research is required to see by how much the feed efficiency and thus farm income can be increased over a full year. The research showed a large variation in feed efficiency leading to a potential increase in farm income of up to €90.000 for the case study farm.

Spring concentrate feeding level was shown to be able to drop to 2 kgs a day on the case study farm, compared to the 3,5 kg advised by Teagasc, without affecting cow health or milk solid production. If the decrease in mineral uptake via concentrates is compensated by providing minerals through boluses and the water system, the average 80 cow Irish dairy herd could save about €2000 in spring concentrate costs.

The research did not show a significant effect of grass variety and year of sowing on feed efficiency or milk production, however there was a tendency. Based on results found in literature, it was concluded that concentrate feed efficiency can further be improved by choosing varieties with a high palatability when reseeding paddocks.

Samenvatting

Het doel van dit onderzoek was om uit te zoeken of, en zo ja, hoe, beweidingsmanagement gebruikt kan worden ter verbetering van de krachtvoerefficiëntie op commerciële Ierse melkveebedrijven. Het onderzoek is uitgevoerd op een commercieel Iers melkveebedrijf met 240 kruisingskoeien op zogenaamde “droge” zanderige leemgrond gedurende de tweede en de eerste helft van de derde beweidingsronde. Data met betrekking tot voerefficiëntie, droge stof cover, grootte van de weilanden, grassoort, bodem P en K waardes en bemesting zijn verzameld uit de aanwezige bedrijfsdata. Weergegevens zijn verkregen van het nationale meteorologische instituut. Omdat de data maar op een bedrijf zijn verzameld moet het onderzoek beschouwd worden als en pilot study. Het onderzoek is een waardevolle bron van informatie over welke beweidingsmanagement factoren de voerefficiëntie kunnen verbeteren, maar meer onderzoek is nodig om te zien of de resultaten ook op andere bedrijven en over een langere periode behaald kunnen worden.

Het onderzoek toont aan dat beweidingsduur per weiland, krachtvoergift en grassoort de potentie hebben om de krachtvoerefficiëntie te verbeteren op een bedrijfseconomisch efficiënte manier. Het beheren van de beweidingsduur per weiland kan het best bereikt worden door over te stappen naar stripweiden. In dit systeem kan het grasaanbod exact worden afgestemd op de behoefte van de koppel. De kosten van deze overschakeling zijn afhankelijk van de aanwezige infrastructuur op het bedrijf, maar bestaan voornamelijk uit verhoogde arbeidskosten. Er is meer onderzoek nodig om uit te zoeken bij hoeveel de voerefficiëntie, en dus het bedrijfsinkomen, verbeterd kan worden over het gehele jaar. Het onderzoek liet een grote variatie in voerefficiëntie zien, met de potentie om het bedrijfsinkomen te verhogen met maximaal €90.000 voor het bedrijf waar het onderzoek is uitgevoerd.

Het was mogelijk de krachtvoergift te laten zakken tot 2 kg op het onderzochte bedrijf, in vergelijking met de 3,5 kg die geadviseerd wordt door de Teagasc, zonder dat het invloed had op de melkproductie of diergezondheid. Als de verminderde mineralenopname door de lagere krachtvoergift gecompenseerd wordt door middel van mineralenbolussen en via het watersysteem, kan het gemiddelde Ierse melkveebedrijf met 80 koeien dus ongeveer €2000 besparen aan krachtvoerkosten in het voorjaar.

Het onderzoek toonde geen significant effect van grassoort of zaaidatum aan op de voerefficiëntie of melkproductie, maar er was wel een neiging tot invloed. Op basis van resultaten in de literatuur, werd geconcludeerd dat de voerefficiëntie nog verder verbeterd kan worden door te kiezen voor grassoorten met een hoge smakelijkheid, wanneer men gaat herzaaien.

1. Introduction

There is a large variation in farm return among Irish dairy farms. Despite the Irish dairy sector consequently being the highest profit agricultural sector in Ireland, this does not mean Irish dairy farmers consequently make a high profit (**Figure 1**), or that there is no room for improvement. For example, there is a large variation between different years, often caused by a variation in input or output prices. This is clearly visible in the 65% increase in family farm income in 2017 compared to 2016 (Dillon, Brian, Lennon, & Donnellan, 2018). Besides this, there is also variation between Irish dairy farmers in the same year. Farms that deliver more milk also generate a higher income (Dillon, Brian, Lennon, & Donnellan, 2018). However, that is not the only cause of the variation in Irish dairy farmers' income. There is also a variation in the financial performance at Irish dairy farms at a litre basis. The net margin ranges from €17.61 per 100 litre in the top third to €11,75 per 100 litre in the bottom third (Teagasc, 2018). A variation in farm income means that there are farms doing better than others and thus the overall performance can be improved. The goal of this research is to find out how the financial farm performance of Irish dairy farms could be improved.

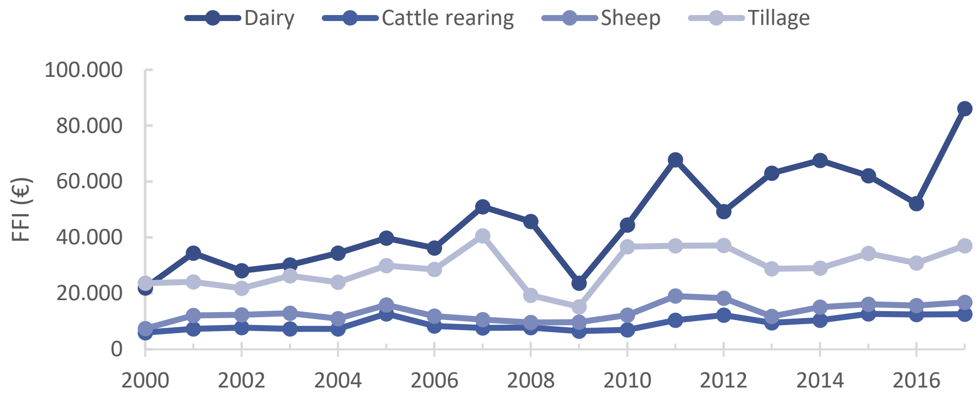

***Figure 1:** Family Farm Income (FFI) of Irish agricultural sectors over time (Teagasc, 2019)*

Variation in financial farm performance

Farm size was shown not to cause the variation in farm income in the Irish dairy sector. Neither does a difference in output price, as the Irish dairy sector produces for a world market, which causes milk prices to be relatively similar for all farms. Thus, the variation will likely come from a difference in costs. Usually, the largest costs on a dairy farm are the fixed costs, such as maintenance of buildings and machinery and, to a certain extent, labour. However, buildings are usually built for the long term and labour is not easily hired or fired. Therefore, there are usually more reasons at play in the choice for a certain building or employee than simply the cost. So, fixed costs do cause part of the variation in farm income, but they cannot be used to improve it.

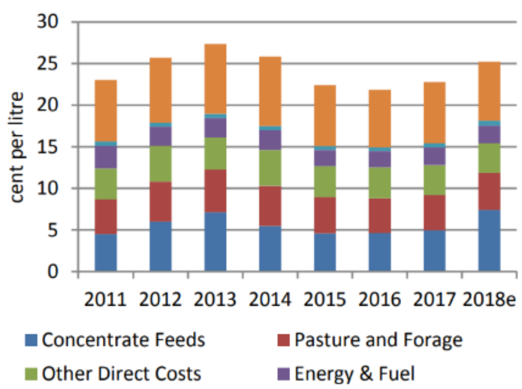

***Figure 2:** Total costs of milk production in Ireland from 2011 to 2018 (O'Connor, 2018).*

The choice for short term farm resources is more likely to be mainly influenced by cost effectiveness. So, variable costs have more potential to be improved in cost effectiveness and improve farm income. Of all costs for milk production, feed costs (concentrate, pasture and forage costs), make up about 40% (**Figure 2**). The Irish dairy sector is characterized as a low-cost, grass-based system. This means roughage (grass) is plenty available and roughage costs are kept as low as possible, as are all costs within the farmer's control. Therefore, decreasing concentrate costs would have the largest potential to improve Irish dairy farmers' income. Farmers themselves have very little influence on the price of concentrate feeds. If, however, the same milk yield could be achieved while feeding less concentrates, this will decrease farm costs and improve farm income.

Maintaining milk yield while feeding less concentrates would have to be an effect of increasing feed efficiency. There is a lot of definitions of feed efficiency. In this research it was chosen to define feed efficiency as "the amount of milk solids produced per amount of concentrates fed" (concentrate feed efficiency). This definition was chosen, because generally all commercial dairy farms record how much milk solids are sold and how much concentrates are bought. So, the efficiency is easily calculated for every farm. It is also the definition which shows most clearly when (concentrate) costs per unit of milk produced decrease. This is opposed to overall feed efficiency or roughage efficiency, which are much more complex as they also include the (fixed) costs for roughages, and the dry matter intake from grass, which is difficult to measure.

Variation in concentrate feed efficiency

That there is variation in milk production per unit of concentrates fed is shown in **Table 1**. Case study 1 is a farm with a relatively young Holstein Friesian herd. The milk production is a lot higher than the Irish average and so is the concentrate feeding level. However, the milk solid production per kg of concentrates fed is higher than the Irish average. Case study 2 is a farm with Jersey cross cows. On this farm the concentrate gift is lower than average, but there is also an above average milk solid production, as well in absolute terms as per kg of concentrates fed. Though these data are from a different year, the deviation is large enough to support the theory of a variation in concentrate feed efficiency, whether it is between different farmers or between different years.

Table 1: *Some farm technical performance indicators of two case studies and national averages*

	Case Study 1 (2016)	Case Study 2 (2017)	Irish Average (2016)	Dutch Average (2016)
Herd size (# cows)	340	190	90[3]	101.2[1]
Production per cow				
Milk (l)	8,500	5,327	5,000[3]	8,482[1]
Fat (%)	3.55	4.56	3.94[4]	4.40[1]
Protein (%)	3.40	3.74	3.39[4]	3.53[1]
Milk solids (kg)	590.7	442	366.5	672.6
Farm performance				
Concentrates/cow/yr. (kg)	1,000	680	800[2]	1,800[2]
Milk (l/ha)	9,259	8,162	6,390	17,324[1]
Cows (#/ha)	1.23	1.53	1.55	2.03[1]
Milk solids (kg/ha)	620	677	570	1,365
Milk solids (kg/kg concentrates)	0.59	0.65	0.46	0.37

[1] (Alfa accountants en adviseurs, 2017) [2] (Hogenkamp, 2017) [3] (The Irish Farmers' Association, 2018) [4] (Central Statistics Office, 2018)

With a higher milk production, the overall feed efficiency improves. This is caused by a dilution effect of the maintenance requirements. The nutrient requirements are divided over more kgs milk, so the feed efficiency per kg milk improves. However, with a low concentrate gift (which is generally the case for Irish dairy farms), the milk production will also be relatively low. This is because concentrates have a higher nutritional density than roughages. Yet, simply increasing concentrate gift to improve feed efficiency will not have a

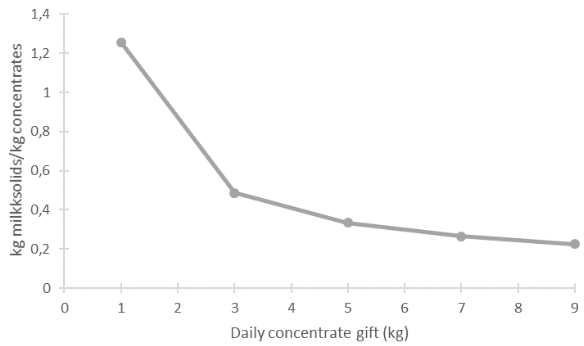

Figure 3*: Milk production per kg of concentrates. Adapted from (De Wit & Van De Goor, 2016).*

direct positive effect on farm income. This is because, to a certain extent, concentrates will be taken up on top of the roughage intake and directly contribute to milk production. Above this threshold, however, adding more concentrates to a cow's diet will decrease roughage uptake. So, the first kgs of concentrates will have the largest impact on milk production and therefore concentrate feed efficiency and farm income. Every kg of concentrates fed more will have a smaller effect on increasing milk production. This is illustrated by **Figure 3**. The difference in milk solid production per kg of concentrates between Ireland and the Netherlands in **Table 1**, shows the same effect on a larger scale.

So, with grass being plenty available and relatively cheap in Ireland but concentrates having to be bought against relatively high prices, a low concentrate gift is often the best strategy for Irish dairy farms. Improvement of farm income could thus be achieved by improving the feed efficiency of these concentrates. However, decreasing concentrate gift to an even lower level to maximise concentrate feed efficiency will not have the desired effect. As the concentrate feeding level is already low, and thus concentrates are being used very efficiently, this will have too large an impact on milk production. Concentrates are also required for other purposes, such as providing the cows with the right micronutrients and to stimulate the cows to come into the milking parlour. Improvement of concentrate feed efficiency should thus be found in other factors. Case study 1 in **Table 1** shows a higher concentrate feed efficiency in combination with a high concentrate feeding level. So, this means that improving concentrate feed efficiency through other factors is possible.

Factors affecting feed efficiency

There are several factors affecting feed efficiency. Not all of them, however, can be used to manage and improve feed efficiency in Ireland. For example, there is several genetic factors causing a variation in feed efficiency. The most obvious genetic factor affecting feed efficiency is difference in breeds. It is well known that Jerseys perform better than Holstein Friesians in terms of feed efficiency. See for example (Kristensen, et al., 2015). This is partly because Jerseys are smaller and thus have a lower nutrient requirement for maintenance. The other part is because Jerseys have a slightly different gastrointestinal system, with a larger small intestine (Groenkennisnet, 2017). This makes them more efficient in taking up the nutrients from their feed. However, case study 1 in **Table 1** managed to achieve an above average concentrate feed efficiency with Holstein Friesians. Besides that, Jerseys being generally more efficient than Holsteins has been known for some time already, and yet not every farmer is milking Jersey cows. So, they must have other reasons in choosing their breed.

Genetic differences within breeds are not suitable to improve feed efficiency and farm income either. The past years there has been a lot of research on genetic factors affecting feed efficiency within breeds (Conor, 2015) (Hurley, et al., 2016), (Hurley, et al., 2017) and defining a breeding value based on these factors (Pryce, Wales, de Haas, Veerkamp, & Hayes, 2014). However, the Irish part of this research started in 2016 and breeding values from other countries are mainly based on body weight and only available for genotyped Holstein Friesian cows (Pryce, et al., 2015). Besides this, the heritability of feed efficiency is relatively low (0.01-0.40 depending on the definition of feed efficiency) (Conor, 2015), and cows with a higher feed efficiency tend to have a more severe negative energy balance. So, this is not a factor that can be used to improve feed efficiency in Ireland, yet.

There is also a variation in feed efficiency within the cow self. Heifers are less efficient than cows. This is because heifers use part of their feed for growth and can therefore only use a smaller proportion of their feed for milk production (Hurley, et al., 2018). So, the maintenance/growth requirements are higher for heifers than for cows. However, case study 1 in **Table 1** managed to achieve an above average concentrate feed efficiency with a relatively young herd. So, this is another factor that cannot explain all variation in feed efficiency and is something farmers often are already trying to improve.

Besides genetic factors itself, the environment also plays a role in whether these genetic factors will be displayed or not. It is generally known that the rearing period has a great impact on a cow's performance later in life through metabolic programming. The effects of colostrum management and illness during the rearing period on milk production are well researched. Colostrum of good quality should be fed in a high enough quantity as soon as possible and illness should be prevented to achieve best results as a dairy cow. However, there is still discussion on what the ideal growth rate for future milk production is (Mourits, et al., 2013). Whether or not growth rate affects feed efficiency remains almost completely unresearched. This is possibly because this requires long term studies and research on feed efficiency in dairy cows is relatively new, as is shown by the research of Hurley et al. trying to define a definition of feed efficiency (2016). Thus, also growth rate during the rearing period cannot be used to improve feed efficiency in dairy cows yet.

Other environmental factors that are logically expected to affect feed efficiency are climate conditions, animal activity and grassland quality. When the temperature falls outside the thermoneutral zone, extra energy is required to cool respectively heat the body and thus less energy is available for milk production. However, climate conditions are hard to influence and not likely to have a large effect on concentrate feed efficiency in Ireland, as the mean temperature variation falls within the thermoneutral zone of dairy cows (mean daily minimum temperature = 2,3°C and mean daily maximum temperature is 19,6°C vs. thermoneutral zone of -15 to +25°C) (MET Éireann, 2019) (Ohnstad, 2012). Animal activity impacts feed efficiency by increasing the energy allocation to movement and decreasing the allocation to milk production, thus decreasing milk yield. It is likely to be mostly influenced by walking distance to the milking parlour and it is generally known that this distance should be minimized. Therefore, the factor with the largest potential to improve feed efficiency in Irish dairy cows is the grazing management and grassland quality.

Improving feed efficiency through grazing management

Grass(land) and grazing characteristics could influence feed efficiency through the interaction between the different types of nutrients between the different feed components. There is proof that there is variation in feed efficiency between different roughages and proportion of concentrates in the ration. For example, there is a difference in milk protein and milk fat content and constitution between white and red clover-grass silage (Steinshamn & Thuen, 2008). Another research with Brown Swiss dairy cows showed no effect of reducing concentrate gifts on milk yields in a low to moderate input production system (Leiber, et al., 2015). However, the call for "an increased research in the area of interaction of supplementary feeds and seasonal effects" in relation to grassland management (Kristensen, Søegaard, & Kristensen, 2005) has not been answered yet.

Grazing characteristics are, to some extent, easy to manage to improve feed efficiency. For example, concentrates usually have a high ruminal passage rate and so does fresh grass. This combination causes the feed relation to pass through the gastrointestinal system quite fast and thus nutrients not being absorbed maximally. If the fresh grass would have more effective fibre, for example by grazing longer grass, this could slow down the passage rate of the ration and improve absorption.

So, grazing characteristics seem to be the most promising factor to improve feed efficiency on Irish dairy farmers. This brings us to the research question:

How can feed efficiency be improved through grazing management?

The goal of this research was to find out if and which grazing characteristics influence feed efficiency, and to form an advice on how to manage these grazing characteristics to improve feed efficiency. The research was conducted on an Irish dairy farm. The research was carried out by collecting data that are easily available on all dairy farms, such as dry matter cover, milk solids yield, date of latest (re)sowing of the grassland, sowed grass species etc. and cow characteristics such as breed, DIL, lactation etc.

In order to answer the research question, logically the first step was to find out *which grazing characteristics influence (concentrate) feed efficiency?* Once this question was answered, one had to find out *how these specific grazing characteristics can be managed*. Together with this question, came the question, *what are the business economic effect of these management adaptations?* After formulating and answering these questions in the second and third chapter, the results were discussed and compared with literature in the fourth chapter. An advice was given to the farmer and the Irish dairy sector on how to improve the feed efficiency through grazing management with the goal to increase farm profits in the last chapter.

2. Materials and method

This chapter describes how the research question "how can feed efficiency by improved through grazing management?" was answered through the sub questions "which grazing characteristics influence (concentrate) feed efficiency?", "how can these grazing characteristics be managed?" and "what are the business economic effect of these management adaptations?".

2.1 Which grazing characteristics influence (concentrate) feed efficiency?

MATERIALS

In order to find out which grazing characteristics influence feed efficiency, data on paddock management, sward management, weather conditions and feed efficiency were collected on a commercial Irish dairy farm (case study). The farm is located near Johnstown Bridge, county Kildare, and has an undulating topography. The soil group is a grey brown podzol, which is derived from limestone drift. This means the farm is what is called a "dry" farm, the soil is generally well drained and is therefore widely suitable for different purposes and the risk of poaching paddocks is relatively small. (Soils Divison, An Foras Talúntais, 1970) The soil on the farm can be classified as sandy loam soil on the slopes and as peat in the valleys, with some seasonal ponds at the lowest parts. The soil type remains relatively constant over the different paddocks, making it possible to compare them with each other.

During the research about 240 Jersey cross cows were milked on this farm. The herd was 100% bred through artificial insemination and. The herd was mostly made up of Holstein Friesian* Jersey (Kiwi cross) cross cows, with a few three way rotaional (Holstein Friesian* Jersey *Scandinavian red) cows. The herd was fully spring calving. The calving took place between 19-01-2019 and 13-04-2019, with 89% of the calvings taking place in a 6 week interval. The calving pattern is shown in **Figure 4**. The herd was on average 3 years and 8 months old at start of the research period and over 76% of the herd had already calved. This compact calving pattern made the farm suitable for this research, as the herd composition remained mostly constant during the research period. The average lactation number was 2,7.

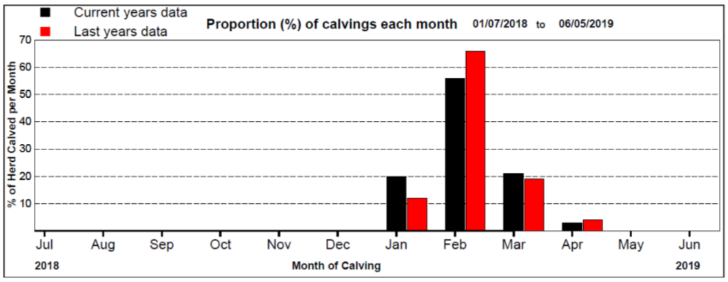

***Figure 4**: Calving pattern 2018 (red) and 2019 (black)*

The data collected on the farm was as followed:

Paddock (short term) management characteristics

- Paddock size (ha)
- Dry matter cover (total DM cover in kg DM/ha per paddock on the day before grazing)

Sward (long term) management characteristics

- Grass varieties
- Year of (re)sowing
- Soil P and K index
- Fertiliser information
  - Date of application
  - Type of fertilizer (artificial fertilizer, slurry or dung)
  - Applied amounts (ton/ha)

- Nutrient content (kg/ton product, obtained from supplier or Fertilizer Association Ireland)
- Working coefficients nutrients (obtained from “Bemestingsadvies” of the Commissie Bemesting Grasland en Voedergewassen)

Weather conditions

- Daily minimum, maximum and grass minimum temperature (°C)
- Rainfall (mm/day)
- Daily average wind speed (knots)

Feed efficiency information

- Concentrate feeding level (kg/cow/day)
- Number of cows being milked
- Number of cows being dumped
- Milk yield (litres, fat % and protein %)

METHOD

The data were recorded during the entire second grazing round and the first half of the third grazing round, from 5-4-2019 until 21-5-2019. The paddock, sward and feed efficiency characteristics were sourced from the available farm data, unless stated otherwise. For one of the paddocks, being paddock 2, the K-level of the adjacent paddock, paddock 1, was used. This is because both paddocks have the same soil type and received the same fertilization, but the samples on paddock 2 were taken soon after spreading slurry. Information on weather conditions was sourced from the Irish national meteorological institution, MET Éireann, based on the data of the closest weather station being Mullingar.

For example, for the dry matter cover the data from the weekly farm walk were used, correcting it with the expected grass growth in that week. For the daily milk yield, the content of the milk bunk tank was recorded after each milking and the fat and protein content was used from the milk collecting data. This method might not give the most accurate data, but it is a time efficient way of data collecting as all used data are normally already recorded on the farm, or easily obtained. These are also the type of data that generally all farmers already collect. So, the results are easy to interpret by farmers and can be compared with other farms.

The data were split up in three categories: the characteristics that could be managed on a daily base (short term management, or paddock management data); the data that could be managed on a longer term (long term management, or sward management data); and the data that could not be influenced (weather data). Per category a combined chart was made in Excel, plotting the data against the milk solid yield, and feed efficiency (in kg milk solids/kg concentrates). In this way, potential relationships could be made visible easily.

Besides plotting the data in different charts, the data were also tested for a significant influence per category. All data were first tested for normality using a normality plot. For the quantitative data a regression analysis was performed to identify significant influences and their size. For the qualitative data a Kruskall Wallis test was performed to identify differences between the different groups.

2.2 How can these grazing characteristics be managed, and what are the business economic effect?

Once it was known which grazing characteristics affected feed efficiency, it was important to find out how these characteristics can best be managed or changed. The two sub questions were answered together as they influence each other: the choice of which management measure to use depends on its business economic effect.

MATERIALS

The most important data were the answer to the first sub question: *Which grazing characteristics influence (concentrate) feed efficiency?* Based on these data a literature research was set up on how to manage these characteristics. This research existed of consulting the Irish Agriculture and Food Development Authority, Teagasc, scientific articles, trade magazines and web shops through the search engines google.com and scholar.google.com.

METHOD

Information on how to manage grazing and grazing infrastructure are was gathered from the Irish Agriculture and Food Development Authority, Teagasc. Scientific resources were consulted to see if the expected result was confirmed by other research. Irish trade magazines and web shops were consulted to determine the business economic effect of changing the management system.

Search terms like “price water troughs Ireland”, “grazing infrastructure” and “concentrate feeding level Ireland” were used. Regarding management decisions, priority was given to the most recent sources from the Teagasc, and after this both scientific articles as well as articles from the Irish trading magazines, The Irish Farmers’ Journal and Agriland, based on date of publication and reliability of the resource behind the article. For the prices regarding the required investments, when no sources of the Teagasc stating average costs were found, the top hits for Irish web shops were considered a suitable indication.

For example, the Teagasc offers plenty of detailed advice on how to develop farm infrastructure for different herd sizes and grazing systems. Together with information from web shops the cost of changing the grazing system could be calculated.

3. Results

This chapter discusses the data that were gathered to answer the different sub questions. The data to answer the first sub question were divided over three paragraphs, regarding the three categories: paddock management (short term management), sward management (long term management) and weather. The data were collected during the second and half of the third grazing round (from 5-4-2019 until 21-5-2019). The data relating to the second and third sub question are discussed together. Only management adaptations that were shown to improve farm income are described.

3.1 Which grazing characteristics influence (concentrate) feed efficiency?

Milk production and paddock management

Data concerning milk yield, concentrate feeding level, dry matter cover and paddock size are shown per paddock in **Figure 5**. Due to mineral related health issues (magnesium deficiency), the concentrate feeding level was raised from 0,7 kg/cow/milking to 1 kg/cow/milking on the 16th of April (indicated with a red "+" sign). The cows were in paddock 16 at that moment. Due to a spilling, the cows were fed additional meal between milkings on the 14th of May (paddock 8, 3rd grazing).

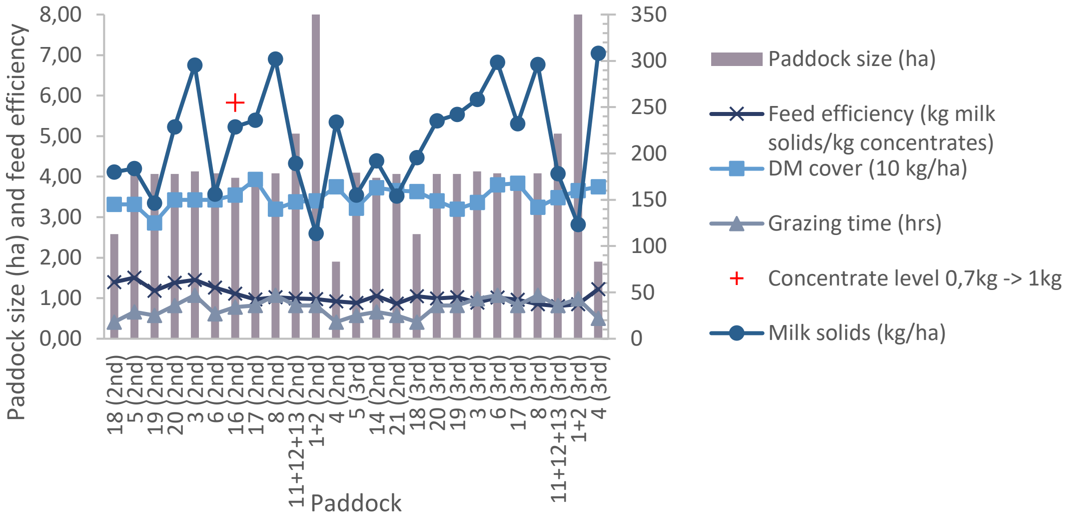

***Figure 5:** Milk production and paddock management*

All data were found to be normally distributed. Out of the factors shown in **Figure 5**, only grazing time (positive) and paddock size (negative) had a significant influence on milk solid production per hectare (**Table 2**). The influence on feed efficiency per paddock was only significant for grazing time (positive) and concentrate feeding level (negative) (**Table 3**).

***Table 2:** Regression analysis of quantitative paddock management parameters on milk solid yield per hectare per paddock*

	Unstandardized β[1]	Standard Error (σ)[2]	Significance (p)[3]
Paddock size (ha)	-37,535	3,485	0,000
DM cover (kg/ha)	0,614	0,402	0,143
Grazing time (hrs)	5,660	1,009	0,000
Concentrates (kg)	-0,003	0,033	0,918

[1] The "Unstandardized β" refers to the size and the direction of the effect. For example, the unstandardized β for paddock size means that the milk solid yield per hectare decreased by 37,535 kg when the paddock size increased with 1 hectare.
[2] The "Standard Error (σ)" refers to the variation in the effect. The larger the standard error, the larger the variation in the results.
[3] The "Significance (p)" refers to the likeliness of the results. In a regression analysis, a p-value<0,05 means it was not proven that the factor had no effect and therefore the hypothesis that there is an effect is accepted.

__Table 3__: Regression analysis of quantitative paddock management parameters on feed efficiency per paddock[4]

	Unstandardized β	Standard Error (σ)	Significance (p)
Paddock size (ha)	0,014	0,029	0,645
DM cover (kg/ha)	-0,002	0,001	0,170
Grazing time (hrs)	0,029	0,005	0,000
Concentrates (kg)	-0,001	0,000	0,000
Milk solids (kg/ha)	0,001	0,001	0,393

Milk production and sward management

Data regarding sward management (long term management), were only analysed for the second grazing round. The third grazing round was not analysed, as not all paddocks were grazed within the research period, leaving insufficient data to be of practical use.

In 2018 soil samples were taken to assess P and K levels in the soil of the different paddocks (**Figure 6**). These indexes are indicated on a level from 1-4. In this system at level 1 crops will certainly respond to fertilisers, at level 4 crops are not expected to respond to additional fertiliser use. The units of these levels are as followed: (Teagasc, sd)

- Level 1: <3,0 mg P/L, ≤50 mg K/L
- Level 2: 3,1-5,0 mg P/L, 51-100 mg K/L
- Level 3: 5,1-8,0 mg P/L, 101-150 mg K/L
- Level 4: ≥8,0 mg P/L, ≥150 mg K/L

***Figure 6:** Farm map with P and K indexes*

Paddocks 11, 12 & 13 and 1 & 2 on the map were treated as one paddock during the research period.

As can be seen in **Figure 7**, all the paddocks received the same amount of P and K previously to their second grazing. Only the amount of urea spread before the second grazing and the P and K-indexes varied. **Table 4** shows the year of sowing and variety of the different paddocks. A normality plot showed that P-index, K-index, available N, milk solid production and feed efficiency were all normally distributed.

***Table 4:** Year of sowing and variety per paddock*

Paddock	Year of sowing	Variety
1+2	2018	1- 60% Abergain + 40% Aberchoice
3	2017	2- 100% Abergain
4	2011	3- Navan + Portstewart + Tyrella + Glenroyal
5	2011	3- Navan + Portstewart + Tyrella + Glenroyal
6	2016	4- Abergain + Tyrella + Glenveagh
8	2016	5- Asten Energy + Tyrella + Glenveagh
11+12+13	2011	3- Navan + Portstewart + Tyrella + Glenroyal
14	2011	3- Navan + Portstewart + Tyrella + Glenroyal
16	2011	3- Navan + Portstewart + Tyrella + Glenroyal
17	2011	3- Navan + Portstewart + Tyrella + Glenroyal
18	2018	1- 60% Abergain + 40% Aberchoice
19	2018	1- 60% Abergain + 40% Aberchoice
20	2018	7- 40% Abergain + 60% Aberchoice
21	2018	7- 40% Abergain + 60% Aberchoice

[4] For an explanation on the interpretation of these results, see the footnotes on page 11.

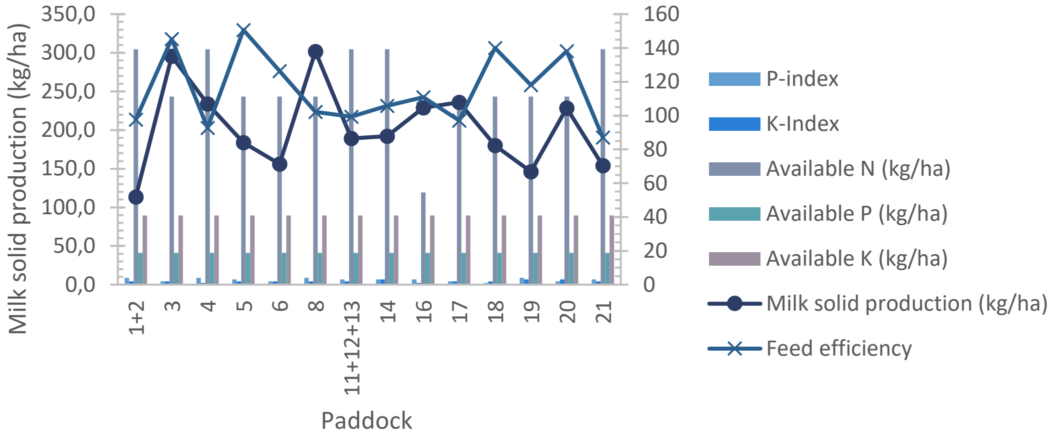

***Figure 7**: Milk production and sward management*

There was no significant effect of available N on milk production per hectare or on feed efficiency (**Table 5**). Neither did P-index and K-index have a significant effect on milk solid production and feed efficiency. Year of sowing and variety did show a tendency of influence on milk solid production, but they did not show a significant influence on milk production efficiency. Paddocks sown in 2018 seemed to perform better than 2011 (p=0,024), 2016 (p=0,077) and 2017 (p=0,025). Variety 1 seemed to perform better than the varieties 2 (p=0,016), 3 (p=0,016) and 5 (p=0,010).

***Table 5:** Regression analysis of quantitative sward management parameters on milk solid yield per hectare per paddock and on feed efficiency per paddock*[5]

	Unstandardized β	**Standard Error (σ)**	**Significance (p)**
Available N (kg/ha) om milk solid yield	-0,736	0,678	0,301
Available N (kg/ha) on feed efficiency	-0,360	0,279	0,227
Milk solids (kg/ha) on feed efficiency	0,028	0,118	0,815

Milk production and weather

The weather and milk yield data per day are shown in **Figure 8**. Unfortunately, weather data from the 17th, 18th and 19th of May were not available for the closest weather station and are therefore not considered.

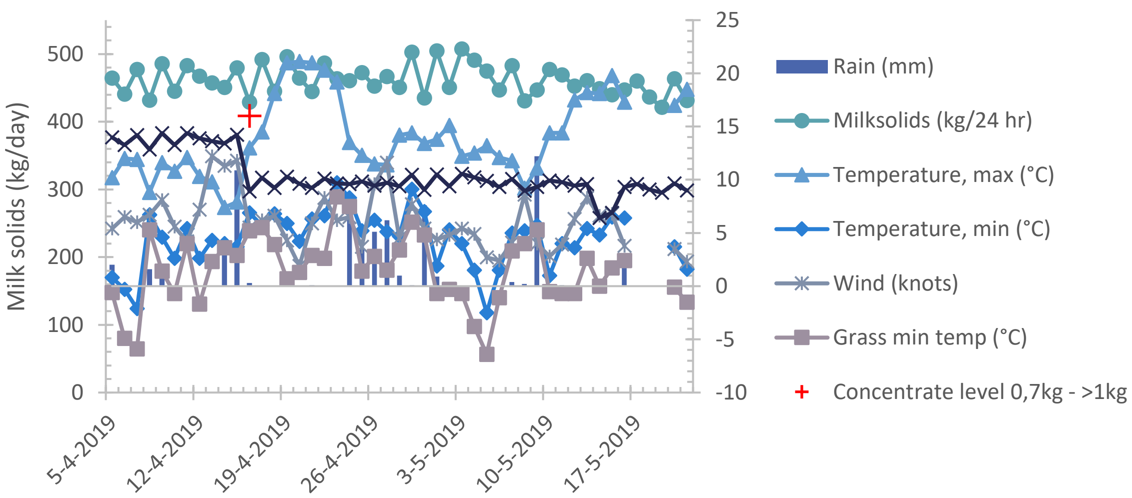

***Figure 8:** Milk production and weather data*

[5] For an explanation on the interpretation of these results, see page 11.

Except for rain, all factors were considered normally distributed. None of the weather factors shown in **Figure 8** showed a significant influence on milk solid production per day, nor where there tendencies of influence (**Table 6**). The maximum temperature and wind speed did show an influence on daily feed efficiency (**Table 7**). With increasing maximum temperature and decreasing wind speed, feed efficiency tended to decrease. There was a significant, negative relationship between concentrate feeding level and daily feed efficiency. Milk solid production per day significantly improved feed efficiency per day.

Table 6: *Regression analysis of weather parameters on milk solid yield per day per hectare*[6]

	Unstandardized β	**Standard Error (σ)**	**Significance (p)**
Rain (mm)	-0,667	1,335	0,620
Maximum temperature (°C)	-0,291	1,296	0,824
Minimum temperature (°C)	1,056	3,657	0,774
Wind (knots)	0,114	1,578	0,943
Minimum grass temperature (°C)	1,521	2,756	0,584

Table 7: *Regression analysis of weather parameters on feed efficiency per day*[6]

	Unstandardized β	**Standard Error (σ)**	**Significance (p)**
Rain (mm)	-0,119	0,091	0,198
Maximum temperature (°C)	-0,238	0,088	0,010
Minimum temperature (°C)	-0,423	0,248	0,097
Wind (knots)	0,206	0,107	0,062
Minimum grass temperature (°C)	0,216	0,188	0,258
Milk solids (kg/ha)	0,022	0,011	0,048

[6] For an explanation on the interpretation of these results, see page 11.

3.2 How can these grazing characteristics be managed, and what are the business economic effect?

Based on the answers to the first sub question, grazing time (per paddock) and concentrate feeding level (per day) were the most likely factors to be able to be managed in order to improve feed efficiency and farm income. This paragraph deals with the practical and economic consequences of managing grazing time per paddock and decreasing concentrate feeding level.

Managing grazing time per paddock

The data showed that a longer grazing time per paddock increases feed efficiency, but a larger paddock size decreases milk solid production per hectare and does not improve feed efficiency per paddock. The grazing time is determined by the paddock size and the dry matter cover in the paddock. Grazing management and paddock layout on the researched farm are designed in such a way that is optimal for three grazings per paddock. However, as dry matter cover and paddock size almost never match the herd's requirements exactly, the cows will almost always be a bit tight for grass during the last grazing in the paddock. A longer grazing time per paddock would decrease this time tight for grass and that is what's likely to affect the feed efficiency.

A longer grazing time per paddock can be achieved by either increasing dry matter cover or by increasing paddock size. The latter one was proven not to be of influence on feed efficiency and to decrease milk solid production per hectare and is therefore not desirable. The former option would mean letting the cows in longer grass. This would mean the grass would have a larger proportion of stem and less leave, resulting in a higher fibre content and lower energy content. This would result in a drop in milk yield and feed efficiency, which was indeed found by (Curran, et al., 2010), and is therefore not desirable as well.

A third potential management tool for grazing time per paddock deals more with the likely mechanism behind the observation: less time tight for grass means a higher feed efficiency. If one could completely let go of the fixed paddock system and use flexible paddocks (strip grazing), the cows would never have to be short for grass. This system, however, requires the installation of extra water troughs and pipes and has a higher demand for daily management. (Tuohy, et al., 2017)

The business economic effect of this change in grazing system depends largely on the existing paddock layout on the farm. The calculation of the business economic effect is therefore performed for the case study farm, as an indication of what the results could be. If an increase in feed efficiency of 0,2 could be achieved over the entire grazing season, the business economic effect of this change in grazing system for the case study could be as followed:

- Returns:
  - Milk check — €95.050[7]
- Costs:
  - Investment 10 extra water troughs (amortised over 15 years): — € 350[8]
  - Reels and stakes: — € 300
  - Opportunity cost labour (€11,50/hour, 0,5 hours/day for 270 days): — € 1.550 -
- Net change in farm income — €92.850

[7] Assuming an increase in feed efficiency of 0,2 (average top 10 paddocks minus total average feed efficiency), 500 kg meal/cow/year, 4,49% fat and 3,59% protein and a milk price of 32 cent/litre

[8] https://www.coopsuperstores.ie (accessed 17-6-2019)

Decreasing concentrate feeding level

Analysis of the daily production data showed that concentrate feeding level did not have a significant influence on milk solid production, and therefore significantly decreased feed efficiency (B=-0,023, se=0,001, p=0,000). This indicates that at low concentrate feeding levels a further reduction of concentrate feeding level could potentially reduce costs without affecting income.

The Teagasc advices a concentrate feeding level of 3,5 kg/cow/day in spring to reach a peak yield of 1,8-1,9 kg milk solids/cow/day. (Kavanagh, 2016) During the research period, the average milk yield, however, was 1,92 kg milk solids/cow/day with an average concentrate feeding level of 1,86 kg/cow/day. So, the same milk yields could be achieved with lower concentrate gifts without feeding other feeds than grass and concentrates. However, during the first time the concentrate feeding level was dropped to 1,4 kg/cow/day health issues arose due to mineral deficiencies. No health issues arose at a concentrate feeding level of 2 kg/cow/day.

If extra minerals were applied in the water system and via boluses, and concentrate gift was dropped to 2 kg/cow/day, this could give the following business economic effect during spring for an 80-cow herd:

- Savings:
  - Feed costs €3240[9]
- Costs:
  - Boluses € 480[10]
  - Minerals in water € 600[4] -
- Net change in farm income €2160

[9] Saving 1,5 kg concentrates/cow/day for 90 days at a price of €300/ton

[10] www.stockhealth.ie (accessed 18-6-2019)

4. Discussion

The goal of the research was to find a way to improve farm income through improving feed efficiency by grazing management. This chapter discusses the limitations of the results found in the previous chapter and compares them to the findings in other literature.

First of all, a remark should be made regarding the interpretation of the results. The research was carried out on one farm, during less than a whole grazing season. This makes the research in fact a pilot study. The results should only be considered as an indication to the direction of the effects, and not as a defined result of changing the grazing management. More research should be done to determine if the same effects can be achieved on different farms and over a longer period.

This is particularly true for the statement that the case study farm could earn €92.280 per year by switching to strip grazing. It is very hard to say what exactly the improvement in feed efficiency will be when using strip grazing, because there was no comparative research done with this system. Also, literature finds varying results regarding different grazing systems and feed efficiency or milk production. For example, Pullido & Leaver (2003), found no evidence of difference in milk yield between rotation stocking and continuous stocking systems, while Macdonald et al. (2008) did find a difference in feed efficiency with different stocking rates (being a higher feed efficiency with higher stocking rates).

The research did find that a reduction in concentrate feeding level can improve feed efficiency, without reducing milk yield. This was shown to be possible by providing extra minerals through boluses and through the water system. Even so, the national advice organ, the Teagasc, does use a higher concentrate feeding level in its advice to farmers. It was not possible to say how this difference in results was caused. Yet, this is something that should be investigated, to avoid unexpected negative side effects of lowering the concentrate feeding level.

In this research, no significant relationship was found between grass variety or year of sowing and milk production and feed efficiency. Most varieties were only sown in one year, which makes it very difficult to say if the tendencies that were seen were caused by either the variety or the year. Other research did find an influence of variety on milk production. For example Tas et al. (2006), found that cultivars with less water soluble carbohydrates gave a lower milk yield, due to a lower intake, although these results were not found in every year. This implies that the effect on milk production is mainly caused by the uptake and thus the palatability of the grass and not so much with the exact nutritional content. This is in correspondence with the observations made during this research. The paddocks including the Glenveagh variety, which is a very thick and unpalatable type, were grazed out less well and were not among the better performing paddocks in terms of milk yield and feed efficiency.

Lastly, the weather data were gathered to check if this did not confound any of the other found relationships. However, the weather data itself was likely to be confounded. The results found a lower feed efficiency with warmer weather and less wind. The warmer weather and less wind, however coincided with the increase in concentrate feeding level. When only the weather data after this increase in concentrate feeding level was considered, the relationships disappeared. The relationship between concentrate feeding level and feed efficiency was significant for the entire data set.

5. Conclusion

The goal of this research was to find out if it is possible to improve the farm income on commercial Irish dairy farms and especially a specific case study by improving the feed efficiency through grazing management. Three factors with this potential were identified. These factors are grazing time per paddock, concentrate feeding level, and grass variety.

Improving feed efficiency through managing grazing time is best achieved by switching to the use of the strip grazing system. In this system the quantity of grass offered can be matched exactly to the herd's requirements. It was not possible to say by how much the feed efficiency would increase exactly, but the variation in feed efficiency exceeded 0,2 points. The cost of switching to this grazing system depends highly on the existing grazing infrastructure but is relatively low and made up mostly by labour costs. Overall, the results showed that a significant increase in farm income can be expected by switching to strip grazing.

Regarding the concentrate feeding level, the case study achieved the same spring milk solid yield as the Teagasc advices, while feeding less concentrates and no other supplements. The average Irish dairy farm could therefore save several thousands of euros per year by dropping the concentrate feeding level. This includes compensating the mineral supply by providing the minerals through boluses and the water system in a cost-effective way.

Sowing paddocks with more palatable grass varieties could further increase feed uptake from fresh grass and improve milk production. In this research it was not possible to attach a certain increase in income to certain grass varieties. Therefore, it is advised to simply give palatability a major role when choosing a variety for (re)sowing paddocks.

So, strip grazing should be used to better match grass offer to the requirements, money could be saved on concentrate costs by providing minerals through boluses and the water system and palatability should be a major consideration when choosing grass varieties. Applying these changes in the management system could significantly improve Irish dairy farmers' income. However, more research over a greater number of farms and a longer period would be required to be able identify the magnitude of the savings and any potential negative side effects.

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Appendixes

I. Checklist schriftelijk rapporteren

Naam: Marieke Dekker
Klas: 4DVb

*De beoordelingscriteria die met een * zijn aangegeven, zijn 'killing points'. Wanneer de beoordelaar daarvan meer dan vijf heeft aangekruist, dien je het rapport/verslag op alle onvoldoende onderdelen te verbeteren. In het afstudeerwerkstuk zijn geen 'killing points' toegestaan.*

1. Het taalgebruik
- ☐ Bevat niet meer dan drie grammaticale, spel- en typefouten per duizend woorden; het rapport/verslag is dan afgekeurd*
- ☐ Heeft een actieve schrijfstijl*
- ☐ Is zakelijk, formeel en objectief *
- ☐ Is coherent (verwijs- en verbindingswoorden)*
- ☐ Heeft een adequate interpunctie*
- ☐ Bevat niet de persoonlijke voornaamwoorden 'ik/ mij/me, jij/je/jou, jullie, u, wij/we/ons' *
- ☐ Is doelgroepgericht*
- ☐ Heeft een uniforme stijl*

2. De ordening
- ☐ Het verslag/rapport heeft een logisch opbouw
- ☐ Elk hoofdstuk heeft een logische alineastructuur
- ☐ Elk hoofdstuk kent een introductie (m.u.v. H.1)

3. Het rapport/verslag
- ☐ Is vrij van plagiaat*
- ☐ De pagina's zijn genummerd*
- ☐ Heeft een uniforme opmaak

4. De omslag
- ☐ Bevat de titel
- ☐ Vermeldt de auteur(s)

5. De titelpagina/het titelblad
- ☐ Heeft een specifieke titel*
- ☐ Vermeldt de auteur(s)*
- ☐ Vermeldt de plaats en de datum*
- ☐ Vermeldt de opdrachtgever(s)*

6. Het voorwoord:
- ☐ Bevat de persoonlijke aanleiding tot het schrijven van het rapport/verslag
- ☐ Bevat persoonlijke bedankjes (persoonlijke voornaamwoorden toegestaan)

7. De inhoudsopgave:
- ☐ Vermeldt alle genummerde onderdelen van het rapport/verslag*
- ☐ Vermeldt de samenvatting en de bijlage(n)
- ☐ Is overzichtelijk/gestructureerd
- ☐ Heeft een correcte paginaverwijzing

8. **De samenvatting:**
- ☐ Is een verkorte versie van het gehele rapport/verslag
- ☐ Bevat de conclusies
- ☐ Bevat suggesties voor verder onderzoek
- ☐ Bevat geen persoonlijke mening
- ☐ Staat direct na de inhoudsopgave

9. **De inleiding**
- ☐ Is hoofdstuk 1*
- ☐ Beschrijft het kader/de context en de aanleiding*
- ☐ Geeft inhoudelijke relevante achtergrondinformatie*
- ☐ Bevat de probleemstelling/de onderzoeksvraag*
- ☐ Vermeldt het doel*
- ☐ Bevat een leeswijzer voor het rapport/verslag*

10. **Materiaal en methode**
- ☐ Beschrijft de gevolgde onderzoeksmethode
- ☐ Motiveert de keuze voor de gevolgde onderzoeksmethode
- ☐ Past bij de probleemstelling/de onderzoeksvraag*
- ☐ Beschrijft de variabelen/eenheden
- ☐ Beschrijft de methode van data-analyse

11. **De (opmaak van de) kern**
- ☐ De hoofdstukken en de (sub)paragrafen met maximaal drie niveaus zijn genummerd*
- ☐ De hoofdstukken en (sub)paragrafen hebben een passende titel
- ☐ Een hoofdstuk beslaat ten minste één pagina
- ☐ Een nieuw hoofdstuk begint op een nieuwe pagina
- ☐ De zinnen lopen door (geen 'enter' binnen een alinea gebruiken)
- ☐ De figuren zijn (door)genummerd en hebben een passende titel (onder de figuur)*
- ☐ De tabellen zijn (door)genummerd en hebben een passende titel (boven de tabel)*
- ☐ Tabellen en figuren zijn zelfstandig te begrijpen
- ☐ In de tekst zijn er verwijzingen naar figuren en/of tabellen*
- ☐ De tekst bevat verwijzingen naar de desbetreffende bijlage(n)
- ☐ De tekst is ook zonder verwijzingen te begrijpen

12. De discussie
- ☐ Vermeldt de interpretatie(s) van de resultaten
- ☐ Bevat een vergelijking met relevante literatuur
- ☐ Geeft de valide argumentatie weer
- ☐ Evalueert de gevolgde onderzoeksmethode
- ☐ Bevat een kritische reflectie op de eigen bevindingen

13. De conclusies en aanbevelingen
- ☐ Bevatten antwoord(en) op de onderzoeksvraag
- ☐ Zijn gebaseerd op relevante feiten
- ☐ Bevatten geen nieuwe informatie*

14. **De bronvermelding**
- ☐ Verwijzingen in de tekst zijn conform de APA-normen*
- ☐ De bronnenlijst is conform de APA-normen*

15. De bijlagen
- ☐ Zijn genummerd
- ☐ Zijn voorzien van een passende titel
- ☐ Bevatten geen eigen analyse
- ☐ Zijn overzichtelijk weergegeven