Benchmarking within CowCompass®

Research Project Veterinary Medicine - Utrecht University

Author: H.H. (Heidy) van Hell BSc*
Supervisors: Dr. G.A. (Gerrit) Hooijer** en H. (Henry) Voogd***

* Master student Farm Animal Health and Veterinary Public Health, Veterinary Faculty, University Utrecht
** PhD, Dipl. ECBHM, Associate professor in ruminant health care Dept. of farm animal health, Veterinary Faculty, University Utrecht
*** Manager CowCompass®

Utrecht University

Prefatory note

Within the training of Veterinary Medicine at the Utrecht University all students have to fulfil a research project. This paper is the final report of the research project carried out by H.H. van Hell. During the research period the possibility of benchmarking farmers and/or veterinarians within CowCompass® has been investigated. Special thanks to Gerrit Hooijer and Henry Voogd for the guidance during this period.

Table of contents

Abstract

Dairy farming has changed enormously in recent years. The consumer demands quality, whereby this quality goes further than just the end product. Consumers are becoming increasingly critical about animal welfare, animal health, public health and food safety. To be able to guarantee this quality and safety, integral quality assurance is increasingly part of the production process. CowCompass® is a Dutch monitoring system that meets the quality assurance requirements of the European Union. Through CowCompass, the risks with regard to animal welfare, animal health and milk quality on the dairy farm are fully analyzed by a certified veterinarian. Since the establishment of CowCompass (2009), a CowCompass has been carried out at 3.000 dairy farms by 400 certified veterinarians. The number of dairy companies, dairy farmers and veterinarians affiliated with CowCompass is increasing. To make participation in CowCompass even more attractive for farmers and to make data from the product even more valuable, the CowCompass Foundation suggested adding an extra dimension: benchmarking. The aim of this study is to investigate the possibilities of benchmarking within CowCompass. The CowCompass Foundation provided a dataset, which consists of the full number of CowCompasses that were carried out in 2017. Based on this dataset, a frequency distribution was made of all critical success factors (CSF) and performance indicators (PI) that are part of the CowCompass analysis. The frequency distribution of the various CSFs and PIs has been converted to a cumulative percentage of all participants, which served as the basis for drawing up the benchmark for farmers. Within the CowCompass system, a score of 5 is seen as the optimum, which is defined as 'low-risk'. Therefore, the aim is to achieve the highest possible score. However, this is not immediately realistic for every farmer. The recommended farmer benchmark is based on feasibility, and provided insight into the most important risks on the dairy farm. Defining this feasibility has taken place in consultation with various parties involved. It has been stated that, if 33% of the farmers achieve this score, the score can be defined as *feasible*. For each CSF and PI this benchmark has been drawn up. The main risks on the participating farms of CowCompass are, among others, feeding and water quality of dry cows, walking space, lying comfort, and disease prevention. In addition, it was investigated whether veterinarians can be benchmarked based on CowCompass. Only veterinarians who have analyzed at least five different dairy farms are included in the veterinary benchmark, representing 204 veterinarians who carried out the CowCompass at 2.335 farms. From the results it is striking that there is a large spread within the median, the first and third quartiles of the veterinarians. During this thesis, no specific benchmark has been drawn up for veterinarians, as there is currently no insight into the cause of the dispersion of veterinarians. The only correct way of benchmarking the veterinarians is sending several veterinarians to one farm, and have them assess this farm independently of each other. Through this, the uniformity of the veterinarians can be examined. Based on the current data set, it is not possible to benchmark veterinarians. Benchmarking farmers can motivate and stimulate to take Dutch dairy farming to an even higher level.

Introduction

Dairy farming has changed enormously in recent years, as the demand for safe and sustainable animal products increased. The European Union Hygiene Regulation (no. 853/2004, Annex II, Section IX, Chapter 1) meets this demand: only milk produced by healthy animals may be processed by dairy companies. The role of the veterinarian at the farm has also been changed for this purpose. A shift has taken place in the field of veterinary practice: previously the curative practice of the veterinarian was central, nowadays prevention is increasingly coming to the fore (LeBlanc *et al.,* 2006). The veterinarian has integral knowledge of livestock farming and animal diseases, which contributes to the safe and sustainable production of animal products.

The consumer demands quality, whereby this quality goes further than just the end product. The entire production process is included in this quality assessment. Consumers are becoming increasingly critical about animal welfare, animal health, public health and food safety. To be able to guarantee this quality and safety, integral quality assurance is increasingly part of the production process. Integral, because the entire chain (including livestock farming) is part of this assurance (Noordhuizen and Metz, 2005; Lievaart *et al.*, 2005). A similar quality system for dairy farms has also been implemented within the dairy chain: CowCompass® .

CowCompass® is a Dutch monitoring system of risk factors for the milk production process, and meets the requirement for quality assurance by the European Union. CowCompass can be used as an instrument for the farmer and veterinarian. The risks with regard to milk quality (e.g. quality parameters as butyric acid, somatic cell count, total bulk somatic cell count), animal welfare (e.g. hock lesions, hygiene) and animal health (e.g. disease incidence) are assessed. In this way it contributes to the further improvement of the quality of the milk, to an animal-friendly production method and to the sustainability of dairy farming. The basic principle of CowCompass is to gain insight into the risks on the dairy farm, so these can become manageable through interventions. As a result, this system contributes to the aforementioned preventive animal health care. CowCompass was developed by veterinarians and dairy farmers at the time, after which it was implemented by dairy companies in the various quality systems. Through CowCompass, a dairy farm is integrally analyzed by the veterinarian and this makes it a unique concept.

Seven critical success factors (CSFs) are used to assess management points that can influence animal health, animal welfare, milk quality and the way in which the milk is produced. These seven CSFs include: milking, feeding and water, housing and husbandry, animal welfare, work routines, animal health and young stock. The CFSs are composed of 40 performance indicators (PI). The PI's are scored between 1 (high risk) and 5 (no risk). The product that CowCompass provides is a risk profile in the form of a diagram (Figure 1).

Figure 1. Example of a CowCompass diagram. The seven Critical Success Factors and the associated score (score 1-5, respectively risky and low risk) (CowCompass Handbook, 2017).

CowCompass produces a risk profile, which is based on data from farmer and veterinarian. The veterinarian adds conclusions and recommendations, so the farmer can optimize work processes. CowCompass is carried out using the CowCompass Handbook. The handbook is a clear document in which explanation is given for the various CSFs and PIs. In addition, it contains various flow diagrams to objectively arrive a certain PI and CSF score. Such a scheme is shown in Figure 2.

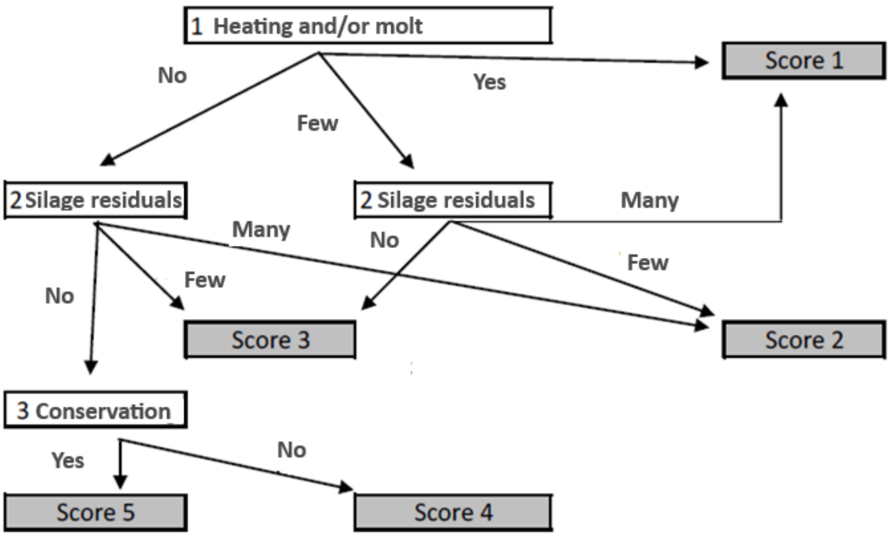


Figure 2. Flow diagram of the performance indicator for Conservation and hygiene of the silage storage (CowCompass Handbook, 2017).

CowCompass was launched in 2009. In the meantime, more than 3.000 farmers have joined the program and around 400 veterinarians are authorized to carry out CowCompass. Authorized, because the veterinarian must follow a six-day course to be able to perform this risk analysis on a dairy farm. Within this course, integral cow management is central and the various risks on dairy farms are highlighted. Through this training, the veterinarian is able to make a risk analysis on the dairy farm. In addition, the veterinarian is trained to formulate specific advices based on this risk analysis.

The number of dairy companies, dairy farmers and veterinarians affiliated with CowCompass is increasing. To make participation in CowCompass even more attractive for farmers and to make data from the product even more valuable, the CowCompass Foundation suggested adding an extra dimension: benchmarking. Where CowCompass is used as a tool for benchmarking between farmers and/or veterinarians. Through benchmarking, farms and veterinarians are compared with each other. The essence of benchmarking is to identify and optimize processes in order to arrive at the best method (Elmuti and Yunus Kathawala, 1997). Benchmarking between farmers can stimulate and motivate them to optimize the processes at the dairy farm in order to bring Dutch dairy farmers to an even higher level. By benchmarking veterinarians, insight can be gained into the uniformity of veterinary assessments. The aim of this thesis is to investigate the possibility of benchmarking farmers and veterinarians using the data from the CowCompass and to formulate an answer to this research question. In addition, appropriate advice is given regarding the design of this benchmark.

Material and Methods

Data collection

For this thesis, a database, supplied by and owned by the CowCompass Foundation, has been used. This database consists of several Microsoft® Office Excel files in which the scores of all dairy farmers and veterinarians of the year 2017 are processed per dairy company. All data has been supplied completely anonymized, as a result the data cannot be traced back to a relevant farmer or veterinarian. A security key has been applied for both cattle farmers (based on unique company number (UCN)) and veterinarians (based on unique veterinary number (UVN)) whereby UCN and UVN are converted into a random number. In total, the data from 11 different dairy companies were available. This results in 2.719 dairy farmers who participated in CowCompass in 2017, carried out by 379 certified veterinarians.

The different scores per CSF and PI per farmer are shown in a figure ranging from the score 1 to the score 5, corresponding to the score that can be achieved with CowCompass. The score per CSF is based on the score of the corresponding PIs. The weighting of the PI depends on the impact of the PI on the CSF and is determined by the developers of the CowCompass. The CSF digit is accurate to one decimal. The score per PI is an exact figure, since the score that can be achieved is only expressed in an exact figure. The different scores per PI are optionally supplemented with a conclusion from the veterinarian in the form of a textual comment. The general conclusion and recommendations are also textually represented in the file. In addition to the scores achieved, a number of key figures (from 2016) of the farms are also shown, namely: the total number of animals on the farm (including young stock), the number of young stock (until calving), the number of dry cows, the number of lactating cows, and the average production of the farm (expressed in kilograms milk per cow per day). The different files have been combined into one Microsoft® Office Excel file, creating an annual overview of both farmers and veterinarians. This file serves as the basis for data selection and data analysis in this study.

Data selection

The available data set consists of the full number of CowCompasses that were carried out in 2017. This implies that every dairy farm is included twice in the data set, since the CowCompass is performed every six months. To prevent interference, it was decided to only include the most recent CowCompass in the analysis. This comes down to a selection of data between 01-07-2017 and 31-12-2017. All available farms were included in the analysis to determine the farmer's benchmark, which results in 2.719 dairy farms. This corresponds to 15% of the total number of dairy farmers in the Netherlands (Central Bureau of Statistics, 2017).

Only veterinarians who have analyzed at least five different dairy farms are included in the veterinary benchmark, representing 204 veterinarians who carried out the CowCompass at 2.335 farms. This means that 175 veterinarians with the associated 384 farms are excluded from participating in the veterinary benchmark. In addition, one CowCompass was removed from the selection because the anonymization of the veterinarian at this company resulted in an unreadable, non-numerical value.

Data analysis

The analysis of data started with determining the frequency distribution per CSF and PI. Based on this, it is determined whether there is a Normal distribution. This is not the case. As a result, the use of an average value for the various CSFs and PIs is not appropriate and the median, and the first and third quartiles are determined for each CSF and PI. To draw up the benchmark, a distinction is made between a benchmark for the farmer and a benchmark for the veterinarian. The frequency distribution of the various CSFs and PIs has been converted to a cumulative percentage of all participants, which served as the basis for drawing up the benchmark for farmers. Within the

CowCompass system, a score of 5 is seen as the optimum, which is defined as 'low-risk'. Therefore, the aim is to achieve the highest possible score. However, this is not immediately realistic for every farmer. The recommended farmer benchmark is based on feasibility. Defining this feasibility has taken place in consultation with various parties involved. The expertise of various experts from the Faculty of Veterinary Medicine at Utrecht University (a.o. Gerrit Hooijer and Frank van Eerdenburg), the manager of CowCompass (Henry Voogd) and the CowCompass Expert Board are used to define a feasible score. It has been stated that, if 33% of the farmers achieve this score, the score can be defined as *feasible*. For each CSF and PI this benchmark has been drawn up.

Prior to the determination of the veterinary benchmark, a determination of the number of CowCompasses per veterinarian was made. Subsequently, all veterinarians the median, and the first and third quartiles of the CSFs of the CowCompasses carried out by this veterinarian were determined. A frequency distribution was made of this median, first and third quartiles. The only correct way of benchmarking the veterinarians is sending several veterinarians to one farm, and have them assess this farm independently of each other. Through this, the uniformity of the veterinarians can be examined. Based on the current data set, it is not possible to benchmark veterinarians.

For this thesis a number of assumptions have been made for the use of the data. The most important assumption here is that the data supplied is correct. After all, at the time of this thesis the results of the farmers/veterinarians were not validated. It is therefore assumed that the scores correspond to the scores obtained based on the CowCompass Handbook. The developers of CowCompass have stated that this document should enable the veterinarian to arrive an objective score (H. Voogd, Personal communication, 2018).

Results

On the basis of the frequency distribution per CSF and PI, it is clear that the scores were not Normally distributed: the scores 4 and 5 were scored significantly more often compared to the scores 1 and 2. Based on the frequency distribution (per CSF and PI) a cumulative percentage has been determined, which provides insight into the most important risks for farmers.

Benchmark for farmers

The benchmark for farmers is based on the aforementioned percentage distribution of the various CSF and PI scores. Premise is, if 33% of farmers can get such a score, this is an achievable score. This score is defined as 'feasible'. An overview of the determined benchmark per CSF and PI is shown in Table 1.

Table 1. Overview of the established benchmarks for the farmer per critical success factor and performance indicator ("feasible for at least 33% of the farmers").

Benchmark for farmers	
Milking	4.8
• Tank room and cooling	5
• Milking method	5
• Hygiene and cleaning	5
• System and maintenance	5
• Animal inspection	5
Food and water	4.2
• Conservation and hygiene	4
• Feeding lactating cows	4
• Feeding dry cows	4
• Water quality lactating cows	5
• Water quality dry cows	4
• Feeding management	5
Housing and husbandry	4.0
• Feed fence	4
• Stall climate	5
• Walking space	4
• Lying comfort	4
Animal welfare	4.5
• Cow activity	5
• Hock score	4
• Hygiene score	4
• Abnormalities	4
• General impression	5
Work routines	4.0
• Crossing lines	4
• Prevention	5
• Grazing	4
• Animal health status	5
Animal health	4.5
• Somatic cell count	4
• Clinical mastitis	5
• Claw disorders	5
• Metabolic diseases	5
• Retention of the fetal membranes	5
• Vaginal discharge	5

• Abortion	5
• Involuntary culling	5
• Other diseases	5
• Current diseased cows	5
Young stock	4.3
• Food and water	4
• Housing	4
• Animal welfare	5
• Disease incidence	4

Critical Success Factor Milking

The CSF Milking identifies the risks for milk quality and the way milk is produced. The score is based on data provided by the farmer. Hereby the veterinarian is expected to validate this data and if desired the veterinarian can perform this part personally. It appears that there is little variation in scores within the CSF Milking (Figure 3). In percentage terms, all farmers achieve a score of 4 or higher, with 13% achieving a score of 5. This is also apparent from the benchmark: 33% of the farmers achieve a 4.8.

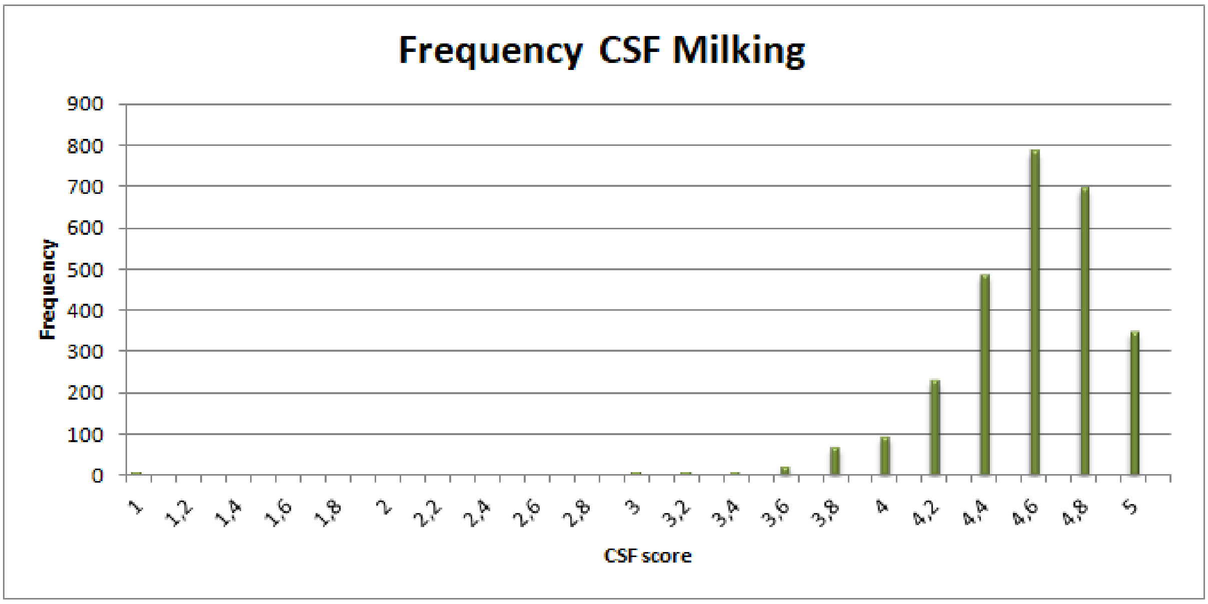


Figure 3. Frequency distribution for the critical success factor (CSF) Milking.

The PIs of this CSF include tank room and cooling, milking method, hygiene and cleaning, system and maintenance, and animal inspection. The benchmark values for the various PIs are set at a score of 5, with farmers achieving at least a score of 3. The exact percentage distribution of the PIs is shown in Figure 4[a-e].

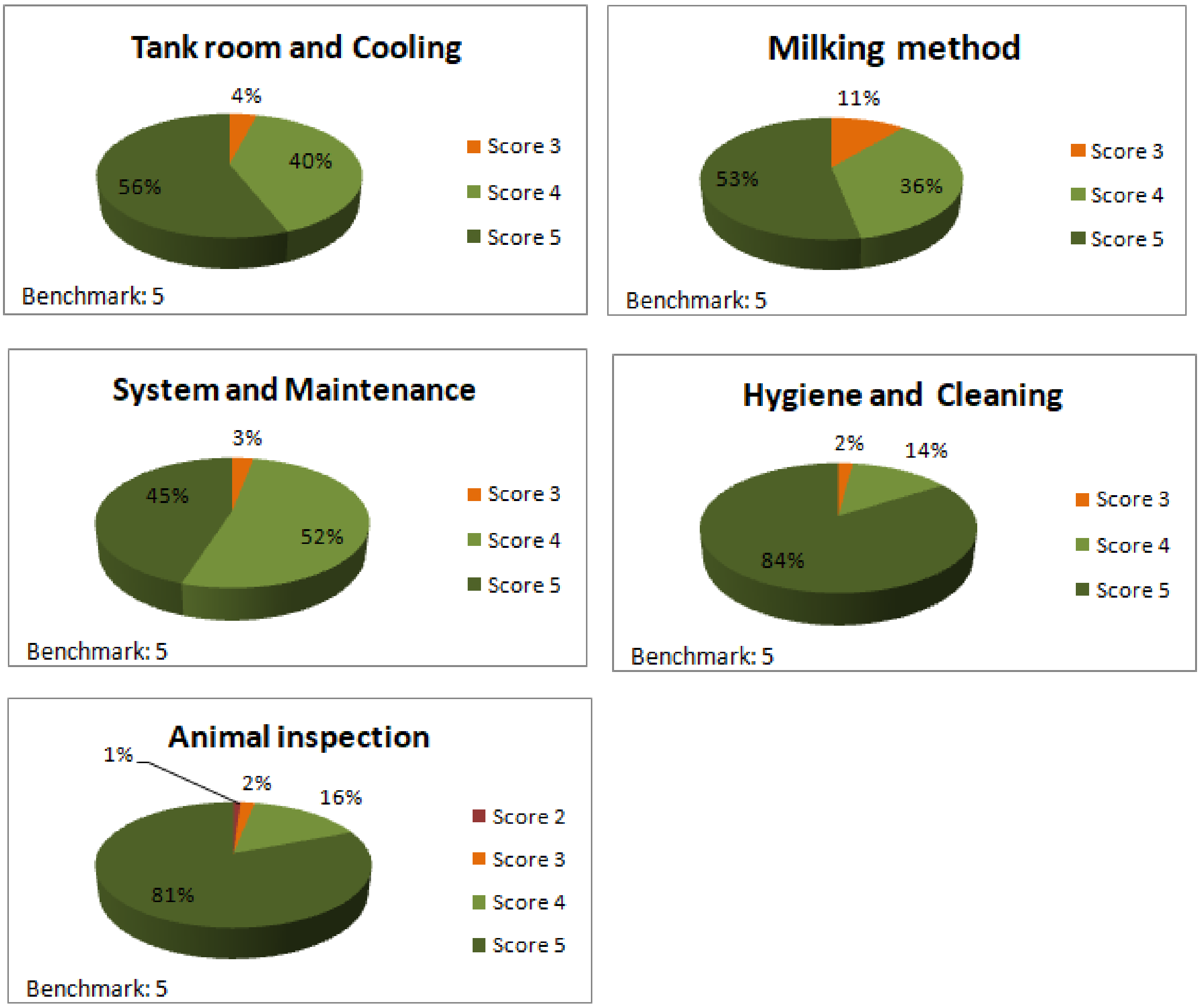


Figure 4[a-e]. Percentage distribution of the performance indicators (PI), which are part of the critical success factor milking. a: PI tank room and cooling, b: PI milking method, c: PI system and maintenance, d: hygiene and cleaning, e: animal inspection.

Critical Success Factor Feeding and Water

The risks that are identified through the CSF Feeding and Water relate to the feed management and water quality of both lactating and dry cows. Figure 5 shows the variation within this CSF. The median of this CSF is 4.0, the first quartile 3.6 and the third quartile 4.4. The benchmark is set at 4.2. Subsequently, the scores of the PIs part of the CSF Feeding and Water, namely: conservation and hygiene of the silage storage, feeding lactating cows, feeding dry cows, water quality lactating cows, water quality dry cows, and feeding management, were analyzed.

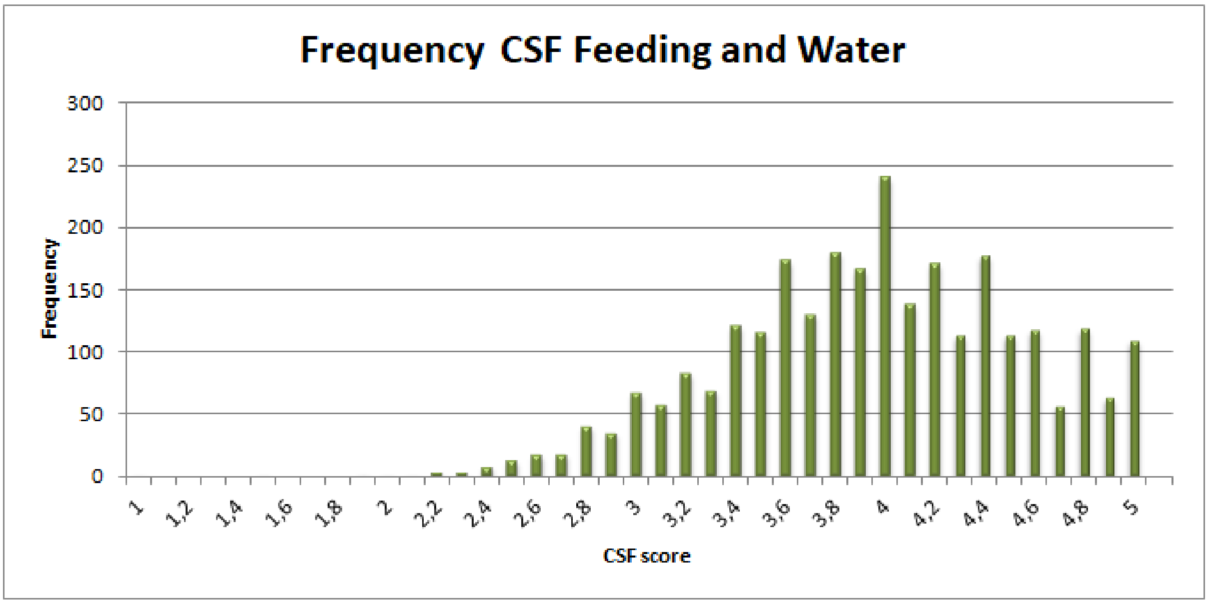
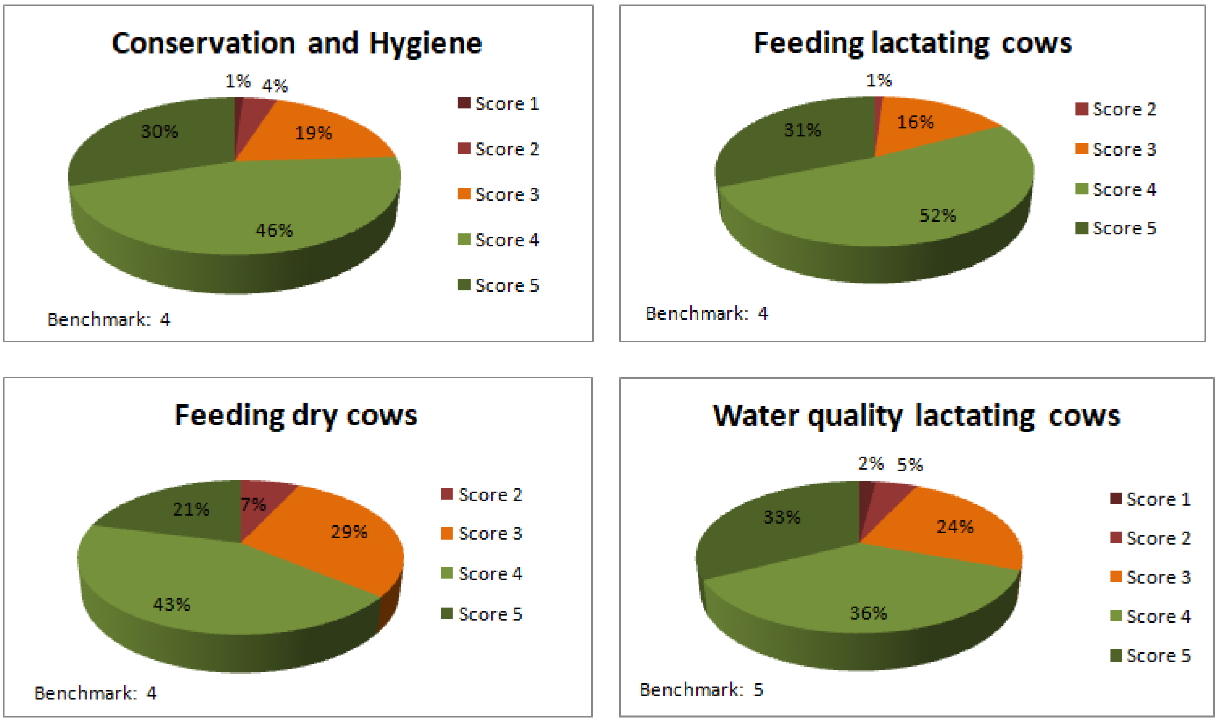


Figure 5. The frequency distribution of the critical success factor (CSF) Feeding and Water.

The percentage distribution of each of the PIs is depicted in the following Figures (Figure 6[o-f]). This shows that especially the PIs water quality (both in lactating cows and in dry cows), and feeding dry cows are risky. However, in case of water quality in lactating cows, the benchmark is set to 5. This is because 33% of the farmers achieve a score of 5. On the other hand, approximately 31% of the farmers achieved a score of 3 or lower.



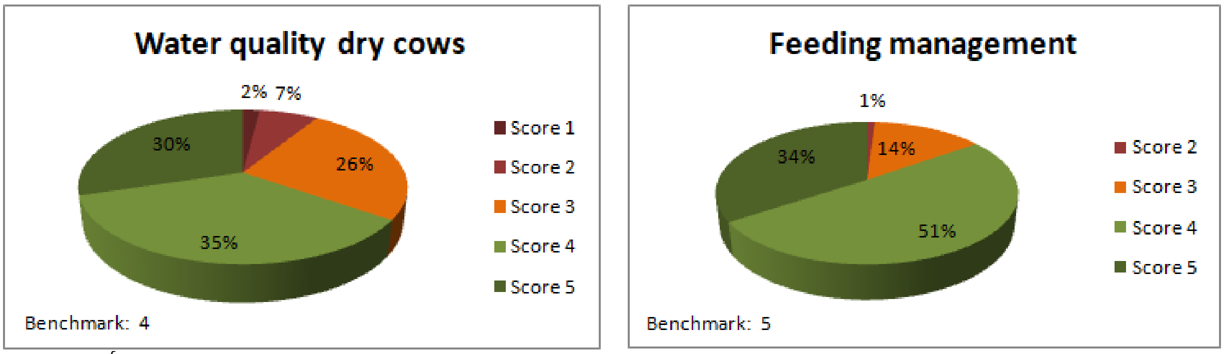


Figure 6[a-f]. Percentage distribution (including benchmark) of the performance indicators (PI), which are part of the critical success factor for food and water. a: PI Conservation and Hygiene of the silage storage, b: PI Feeding lactating cows, c: PI Feeding dry cows, d: Water quality lactating cows, e: Water quality dry cows, f: Feeding management.

Critical Success Factor Housing and Husbandry

The CSF Housing and Husbandry identifies the risks with regard to the housing of the animals. Figure 7 shows the frequency distribution of this CSF. Likewise, a large spread in scores is visible, with the benchmark set to 4.0. This is the lowest benchmark score for the various CSFs. Analysis shows that 22% of the farmers achieve a score 3 or lower and only 3% of the farmers score a 5.

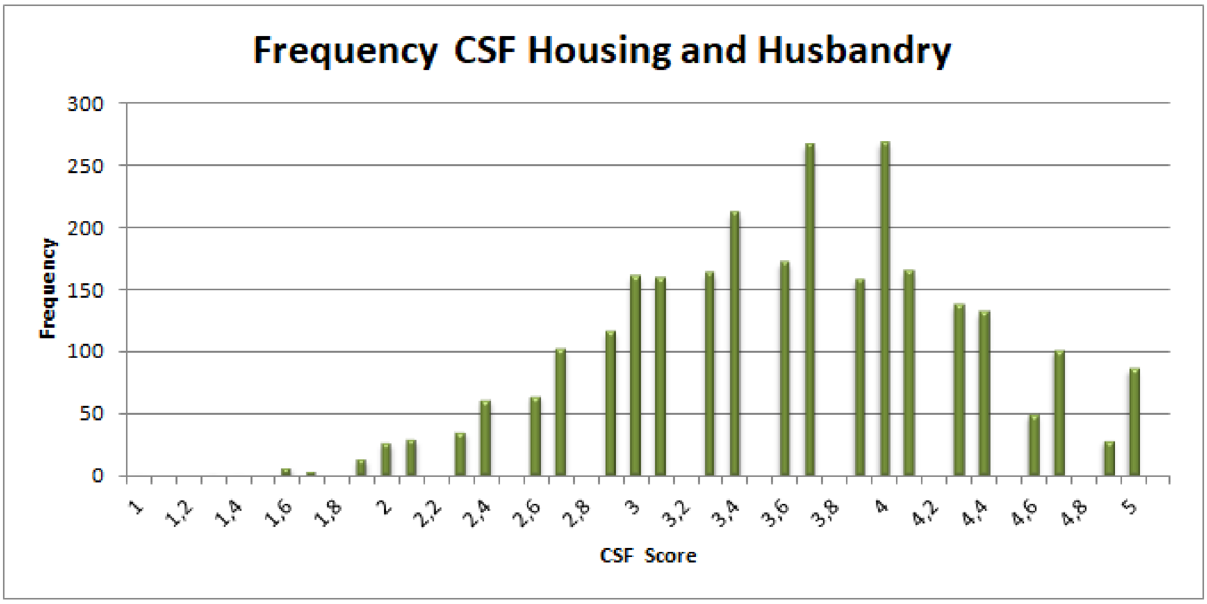


Figure 7. The frequency distribution of the critical success factor (CSF) Housing and Husbandry.

The CSF Housing and Husbandry consists of the PI's feeding fence, stall climate, walking space, and lying comfort. The percentage distribution of the aforementioned PIs are shown in Figure 8[ad]. This shows that in particular the walking space and lying comfort are at high-risk, respectively 19% and 11% of the farmers score a 2 or lower.

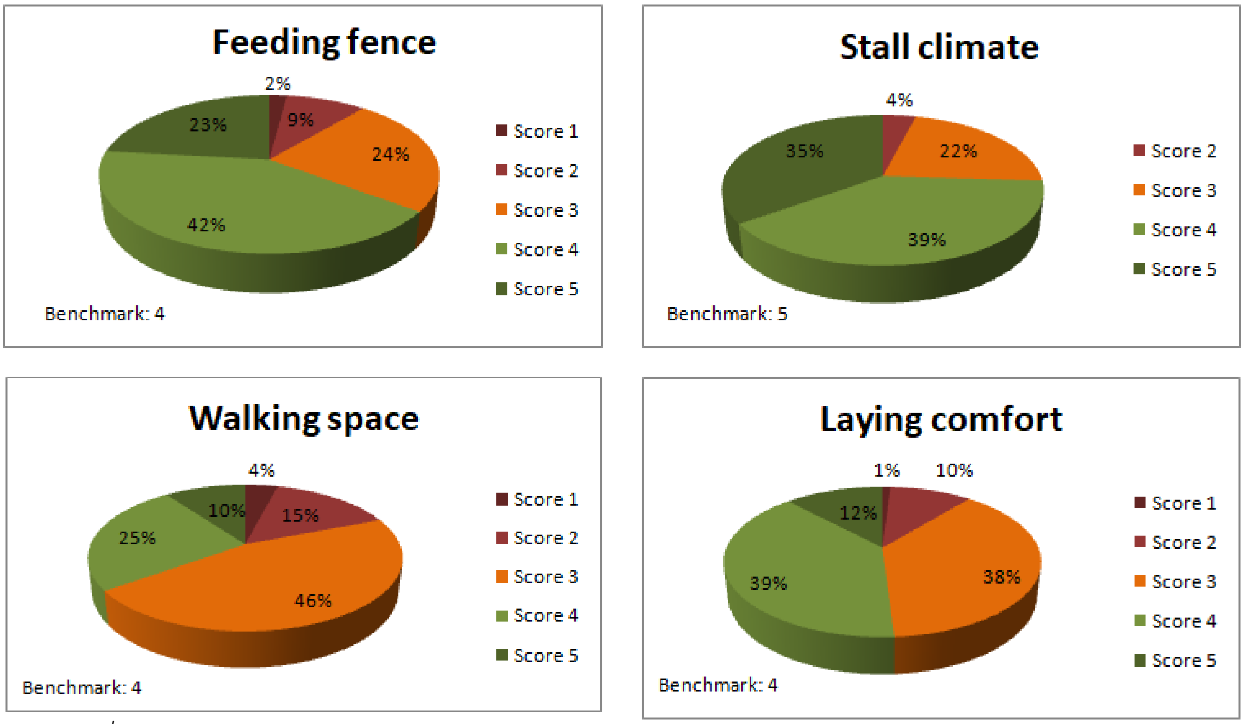


Figure 8[a-d]. Percentage distribution (including benchmark) of the performance indicators (PI), which are part of the critical success factor for housing. a: PI Feeding fence, b: PI Stall climate, c: PI Walking space, d: Lying comfort.

Critical Success Factor Animal welfare

The CSF Animal welfare provides an inventory of the risks with regard to animal welfare. The frequency distribution is shown in Figure 9. In percentage terms, 95% of the farmers score a 4 or higher. The animal welfare benchmark is set at 4.5. The CSF Animal welfare is made up of the PIs cow activity, condition score, locomotion score, hock score, hygiene score, abnormalities and general impression. The percentage distribution of these PIs is shown in Figure 10[a-e]. The percentage distribution of both the condition score and the locomotion score are not shown, as not all the data from these PIs is not expressed in a score of 1 to 5. The greatest risks can be found in PI hock swelling and PI hygiene: 28% of the farmers score a score 3 or lower on heel swelling, and this applies to 38% of the farmers on the PI hygiene.

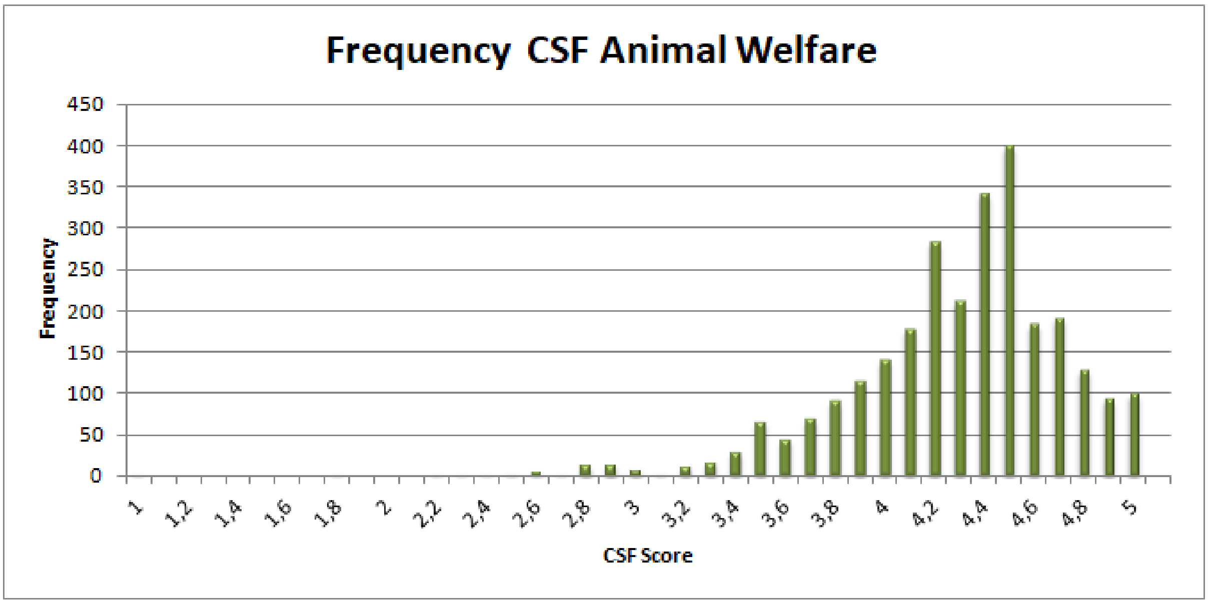


Figure 9. Frequency distribution critical success factor (CSF) Animal welfare.

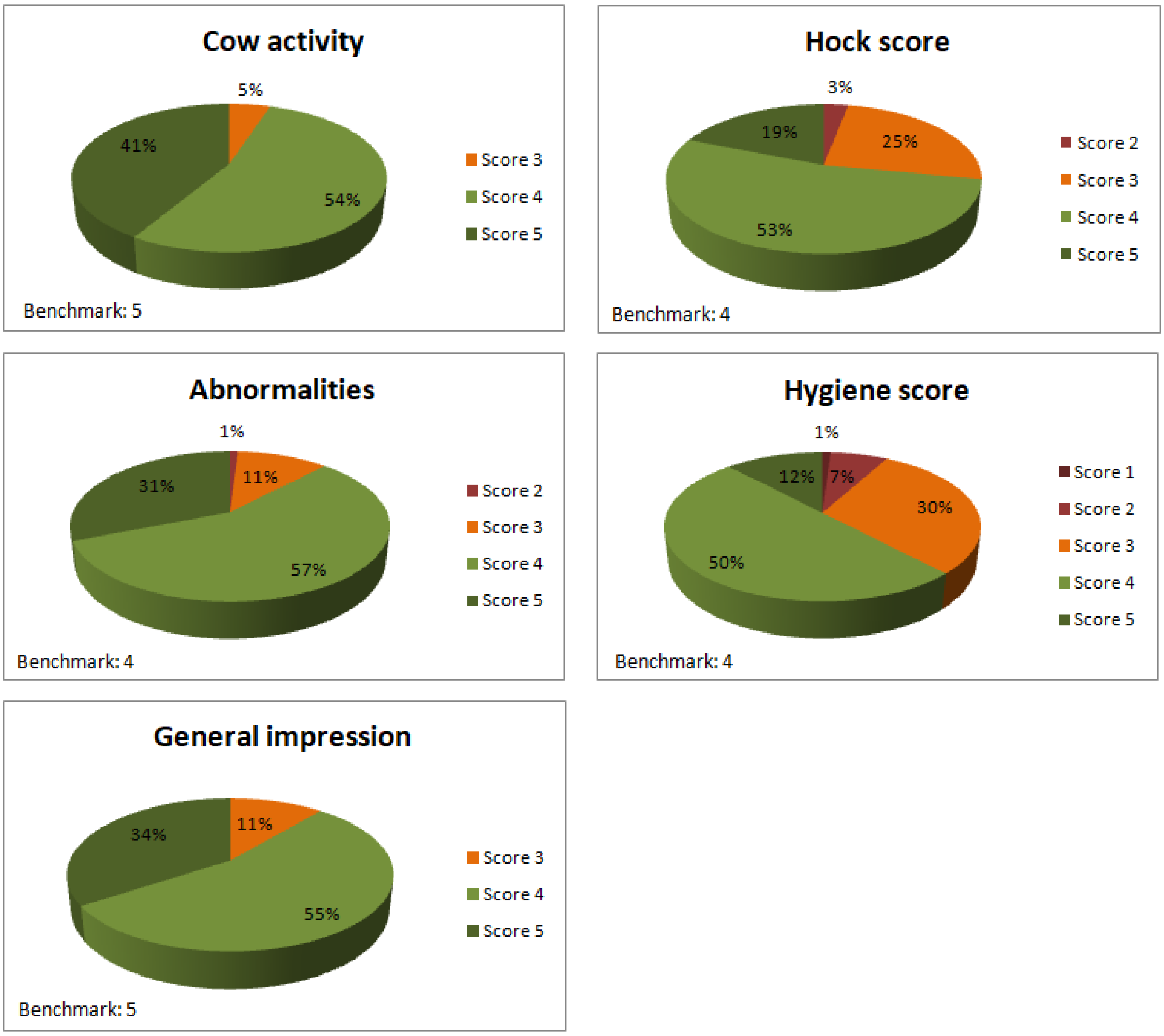


Figure 10$^{a\text{-}e}$. Percentage distribution (including benchmark) of the performance indicators (PI), which are part of the critical success factor animal welfare. a: PI Cow activity, b: PI Hock score, c: PI Abnormalities, d: PI Hygiene score, e: PI General impression.

Critical Success Factor Work routines

The risks that are analyzed through the CSF Work routines mainly relate to preventive measures and the animal health status of the company. Figure 11 shows the frequency distribution for this CSF, with the benchmark set at 4.0. This value is comparable to the CSF Housing and Husbandry and therefore has the lowest benchmark value for a CSF. Approximately 9% of the farmers achieve a score of 3 or lower.

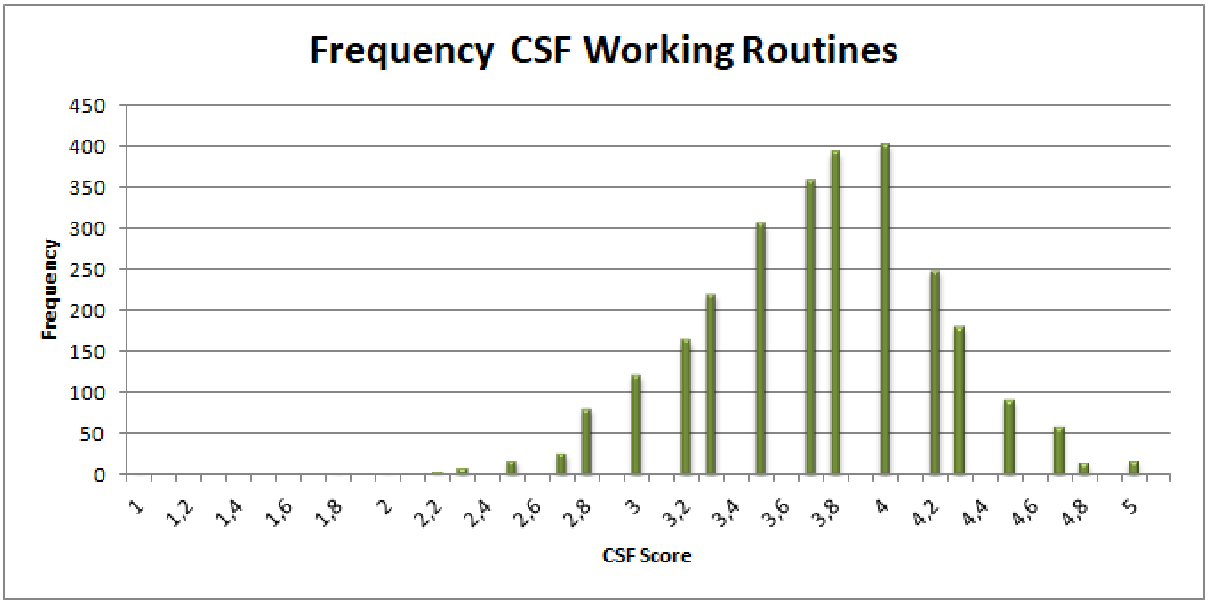


Figure 11. Frequency distribution critical success factor (CSF) Work routines.

The CSF Work routines is made up of the PIs animal health status, other vaccinations (e.g. Bovine respiratory syncytial virus, *Trichophyton)*, preventive measures, crossing lines of manure and feed, farm specific treatment plan and grazing. The scores for the PI animal health status and prevention of animal disease are based on data provided by the farmer and veterinarian. The percentage distributions of the PIs are shown in Figure 12[a-d]. There is no specific score associated with the PI other vaccinations and is therefore not shown in the figure. All farmers scored a score of 5 on the PI farm specific treatment plan, which means that the farm specific treatment plan is evaluated annually on all farms. The percentage distribution shows that the PI prevention, in particular, is risky as 68% of the farmers achieving a score 3 or lower. In addition, crossing lines of manure and feed are also a risk, with 37% of the farmers achieving a score of 3 or lower.

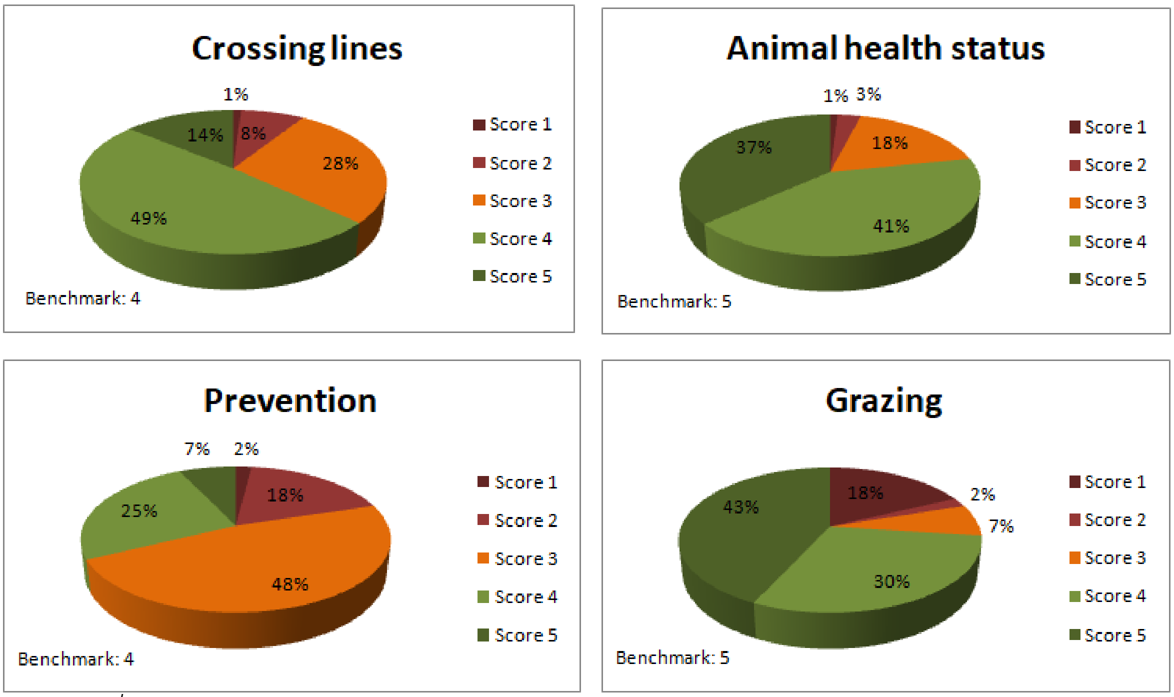


Figure 12[a-d]. Percentage distribution (including benchmark) of the performance indicators (PI), which are part of the critical success factor work routines. a: PI Crossing lines of manure and feed, b: PI Animal health status, c: PI Prevention, d: PI Grazing.

Critical Success Factor Animal health

The CSF Animal health provides insight into animal health, the use of antibiotics and culling of animals. The frequency distribution for this CSF can be found in Figure 13. The benchmark has been set at 4.5 and this implies that the farmers score relatively high. This is also apparent from the percentage distribution: 90% of the farmers score a 4 or higher.

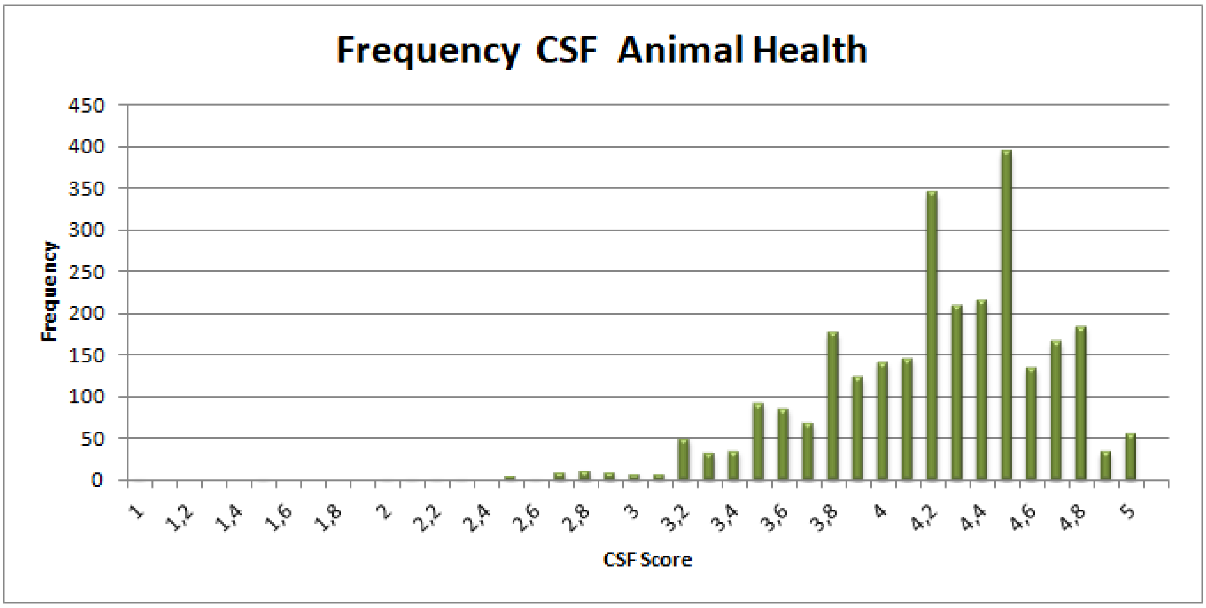


Figure 13. Frequency distribution critical success factor (CSF) Animal health.

The CSF consists of 11 different PIs, namely: antibiotic use, high somatic cell count, clinical mastitis, claw problems, metabolic disease, retention of the fetal membranes, vaginal discharge, abortion, involuntary culling, other diseased animals and attention animals. For the assessment of the animal health, the incidence of diseases of the past 6 months is automatically calculated back to an annual average. This data is supplied by the farmer. The percentage distribution per PI and the associated benchmark are shown in Figure 14[a-d]. The benchmark for high somatic cell count is a score 4. The other PIs have a benchmark value of 5. The PIs for involuntary culling and other animal diseases are not shown, since 100% of the farmers achieved a score of 5. In addition, the PIs retention of the fetal membranes, vaginal discharge, abortion and attention animals, are neither shown since 99% of the farmers achieved a score of 5. The remaining 1% scores a 4. The risk of these PIs is therefore small. The PI antibiotic use is not expressed in a score and is therefore not shown in the figure.

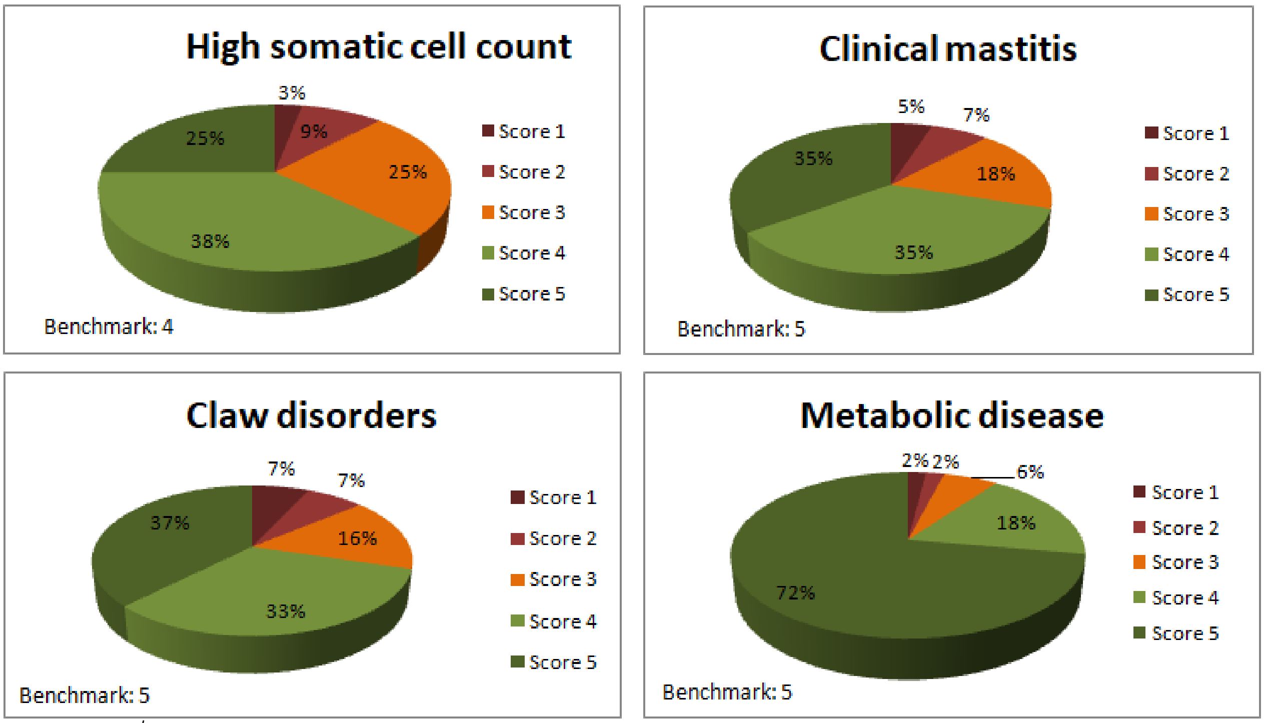


Figure 14[a-d]. Percentage distribution (including benchmark) of the performance indicators (PI), which are part of the critical success factor animal health. a: PI High somatic cell count, b: PI Mastitis, c: PI Claw disorders, d: PI Metabolic disease.

Critical Succes Factor Young Stock

The CSF Young Stock identifies the potential risks within raising young stock. The aim of raising young stock (according to the CowCompass Handbook) is to produce a healthy heifer, which calves easily, and then quickly gives milk in sufficient quantity of good quality. If the young stock is outsourced and no calves or heifers are present at the time of the visit, a 3 is scored. The frequency score for this CSF is shown in Figure 15. The median is 3.8, the first quartile at 3.5 and the third quartile 4.3. Approximately 60% of the farmers score a 4 or higher on this CSF. The benchmark is set at 4.3.

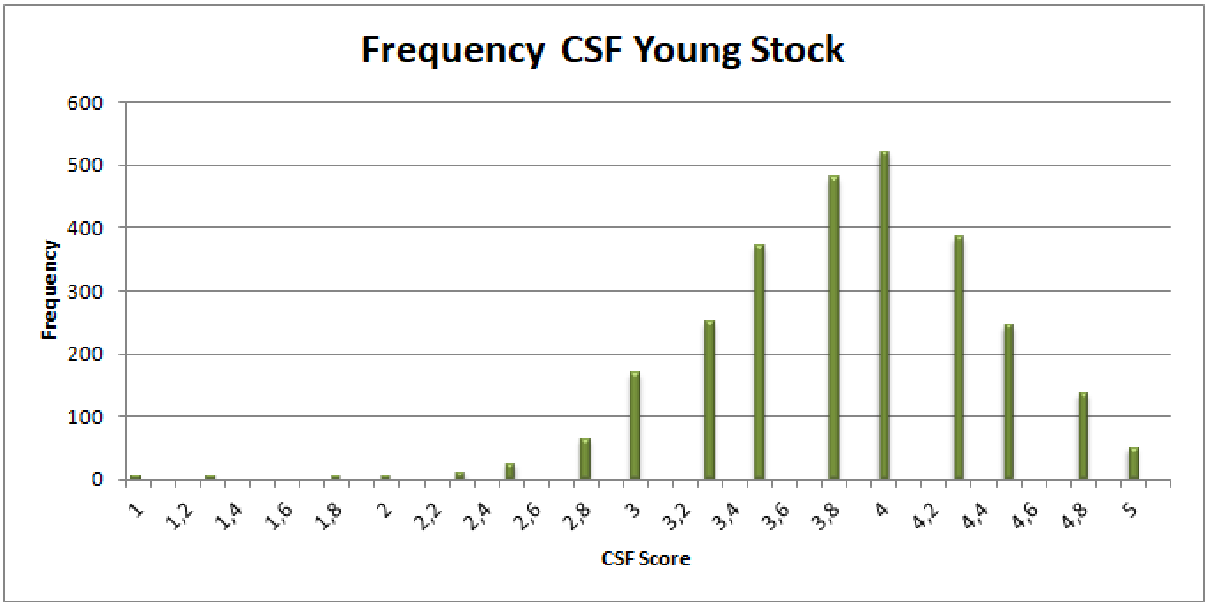
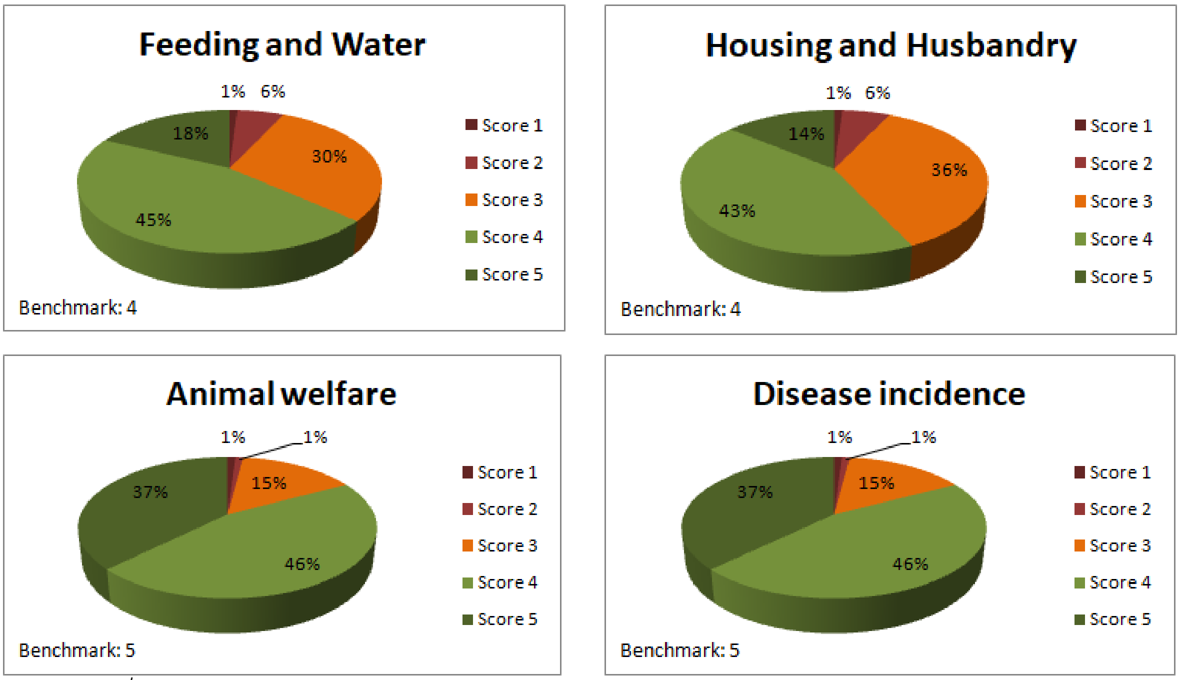


Figure 15. Frequency distribution critical success factor (KSF) Young stock rearing.

This CSF is subdivided into the following PIs: feeding and water, housing and husbandry, animal welfare, and disease incidence. The percentage distribution of these PIs is shown in Figure 16[a-d]. The PI animal welfare is scored highest, followed by animal disease incidence.



Figures 16[a-d]. Percentage distribution (including benchmark) of the performance indicators (PI), which are part of the critical success factor for young stock. a: PI Feeding and Water, b: PI Housing and Husbandry, c: PI Animal welfare, d: PI Disease incidence.

Benchmark for veterinarians

In order to gain insight into the number of CowCompasses that a veterinarian carries out, a frequency distribution has been made (shown in Figure 17). Approximately 17% of veterinarians have performed CowCompass on only one dairy farm. Only veterinarians who have performed at least five CowCompasses in the specified period are included in the analysis. This results in 54% of the veterinarians.

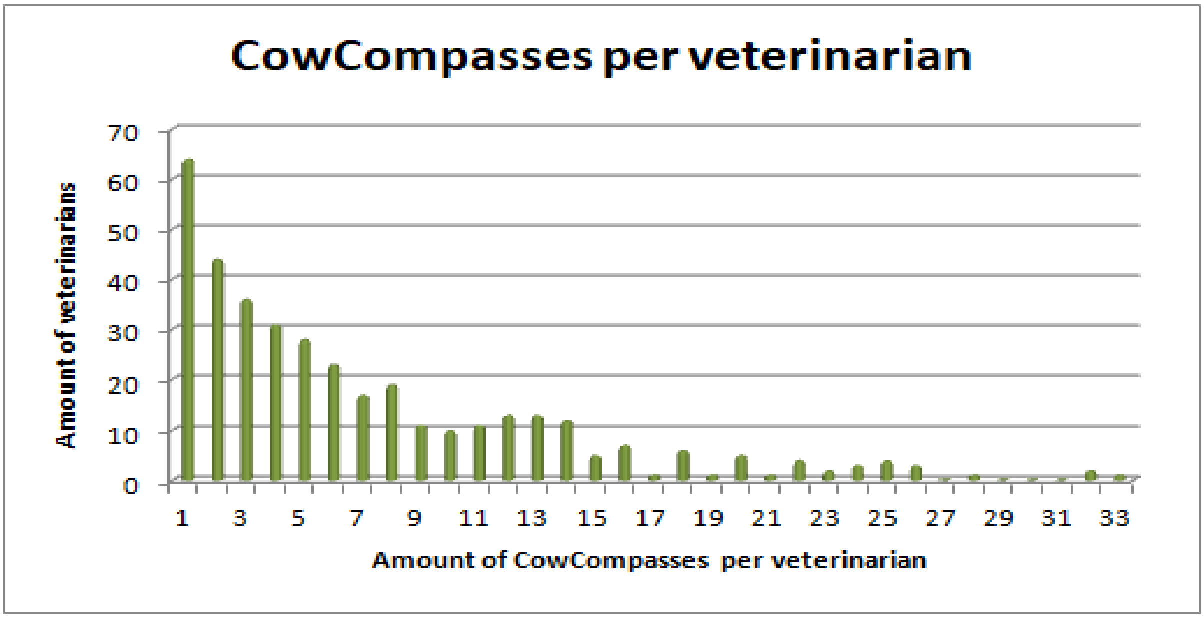


Figure 17. Frequency distribution of the number of CowCompasses performed per certified veterinarian in the period 01-07-2017 - 31-12-2017.

For each CSF a frequency distribution is determined of the median, first and third quartiles of the selected veterinarians. The factors with the greatest variation are shown and are further described. Please refer to the appendix for the figures of the CSF Milking, Work Routines and Animal health. Within the CSF Milking, the median of the selected veterinarians varies from 4.2 to 5.0. The spread width is 0.8 on a scale of 5. The first quartile varies from 4.0 to 4.8 and the third quartile from 4.5 to 5.0. The CSF Milking has the smallest spread. The frequency distribution for the median of the CSF Feeding and Water is shown in Figure 18. This varies from 2.8 to 5.0, with 49% of the veterinarians having a median of 4 or higher. The frequency distribution of the first quartile (Q1) is shown in Figure 19. The median varies from 2.5 to 5.0. This is a spread width of two and a half points on a scale of 5. The frequencies of the third quartile (Q3) are shown in Figure 20, which varies from a score of 3.0 to 5.0. Approximately 3% of veterinarians have a Q3 of 5.

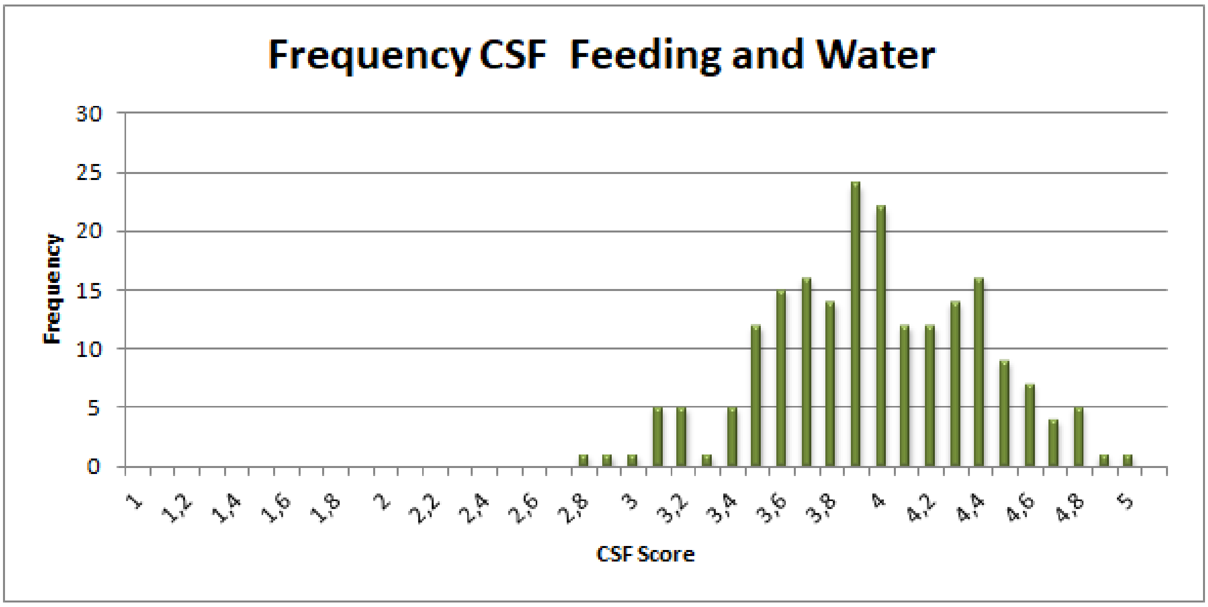


Figure 18. The median frequency distribution of the selected veterinarians for the Critical Success Factor (CSF) Feeding and Water.

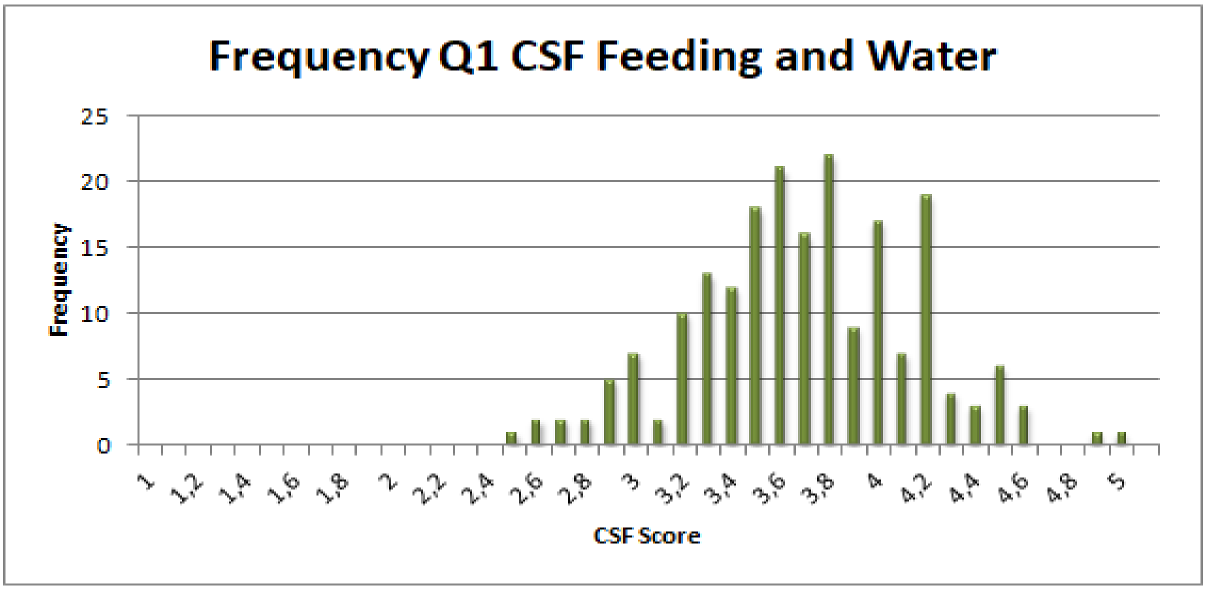


Figure 19. The frequency distribution of the first quartile (Q1) of the selected veterinarians for the Critical Success Factor (CSF) Feeding and Water.

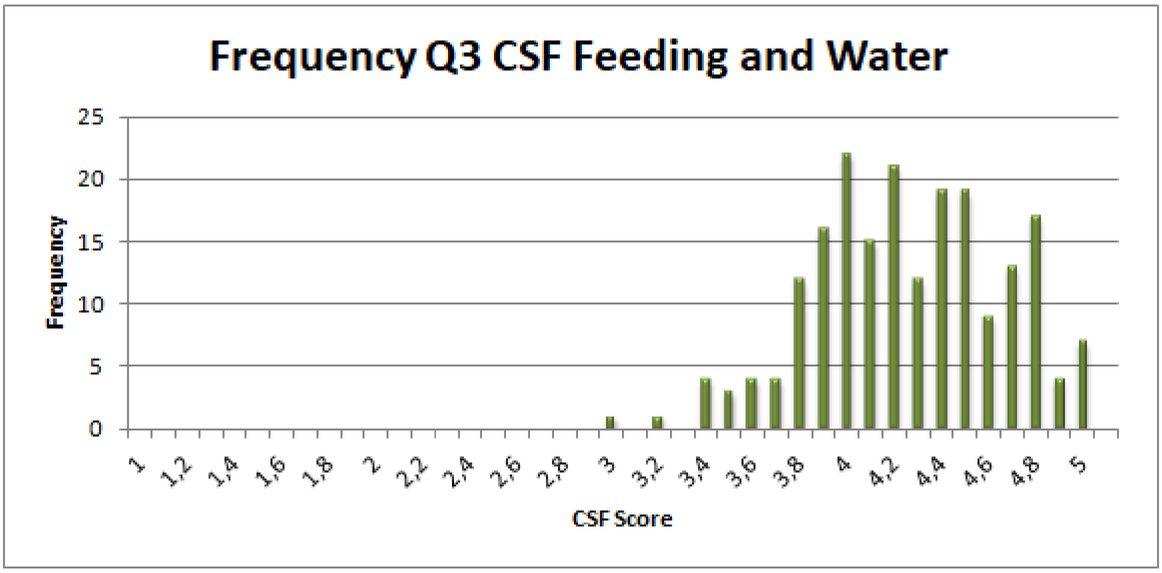


Figure 20. The frequency distribution of the third quartile (Q3) of the selected veterinarians for the Critical Success Factor (CSF) Feeding and Water.

A similar spread is visible within the CSF Housing and Husbandry (Figure 21). The spread width of the median is 2.6, as it varies from 2.4 to 5.0. The spread of Q1 is shown in Figure 22, and a considerable spread can also be observed. One veterinarian has a first quartile of 5.0. The frequency distribution for Q3 is shown in Figure 23, where it varies from 2.6 to 5.0.

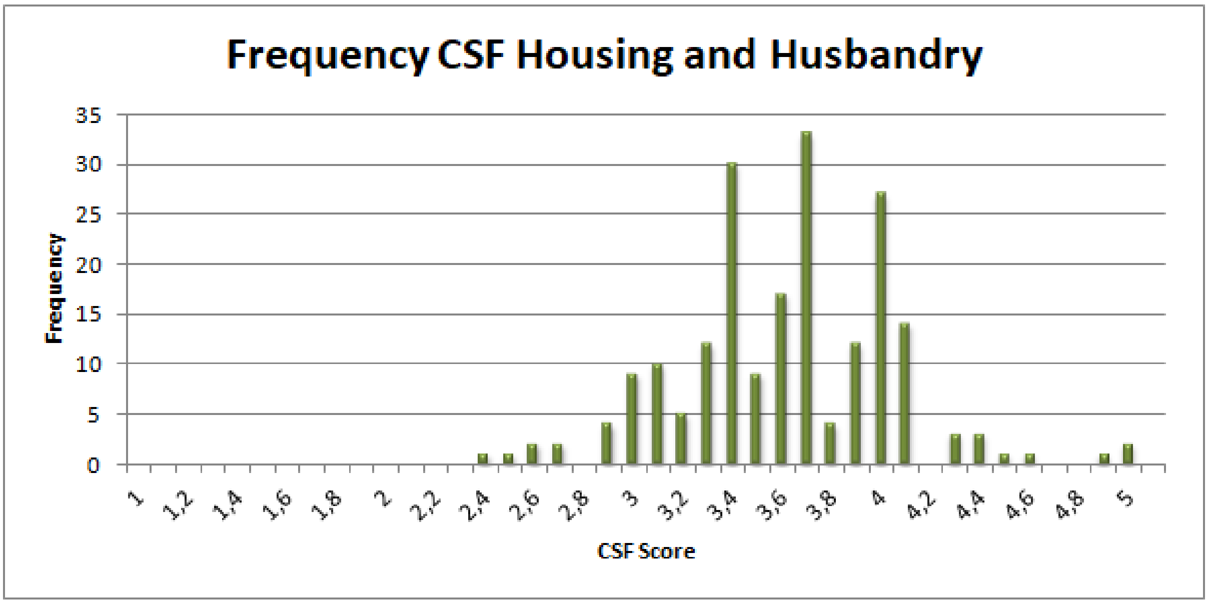


Figure 21. The median frequency distribution of the selected veterinarians for the Critical Success Factor (CSF) Housing and Husbandry.

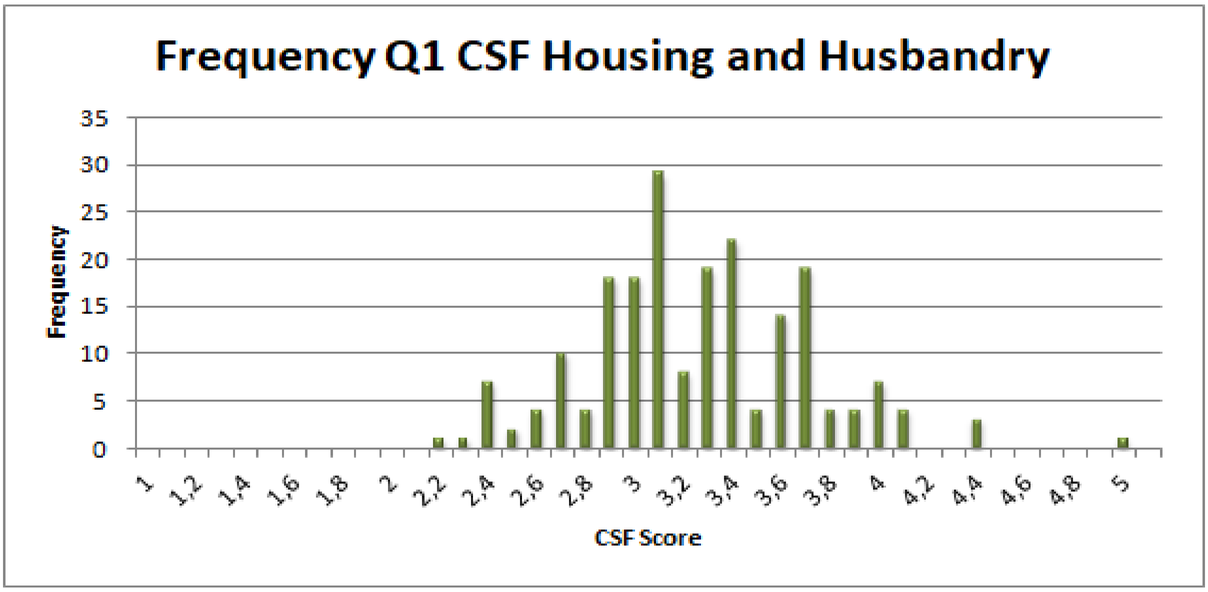


Figure 22. The frequency distribution of the first quartile (Q1) of the selected veterinarians for the Critical Success Factor (CSF) Housing and Husbandry.

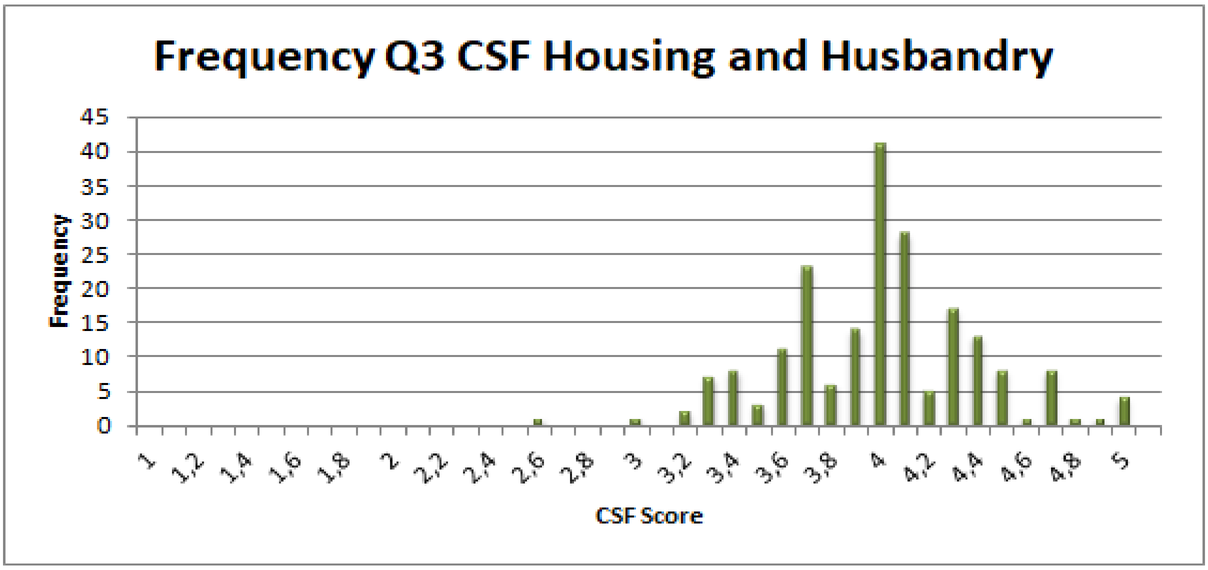


Figure 23. The frequency distribution of the third quartile (Q3) of the selected veterinarians for the Critical Success Factor (CSF) Housing and Husbandry.

The median of the CSF Animal welfare shows the same spread, varying from 2.9 to 5.0. This implies a spread width of 2.1 on a scale of 5. The frequency distribution of the median is shown in Figure 24. The spread of the Q1 and Q3 is shown in Figure 25 and Figure 26, respectively. The spread width for Q1 is 2.0, as it varies from 2.9 to 4.9. The Q3 varies from 3.8 to 5.0.

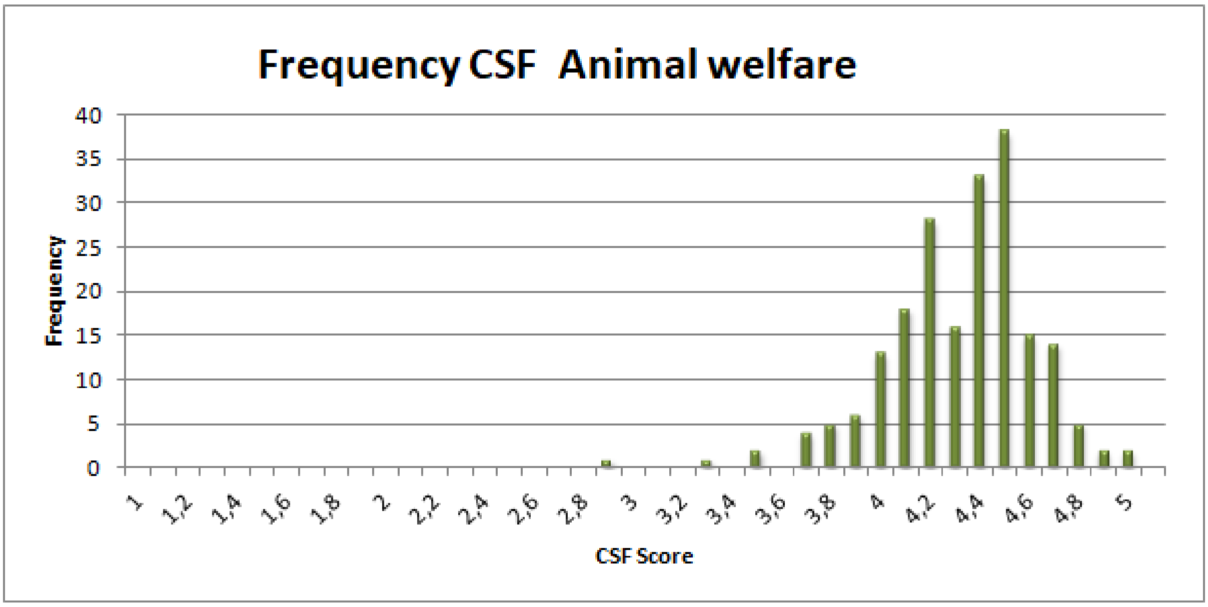


Figure 24. The frequency distribution of the median of the selected veterinarians for the Critical Success Factor (CSF) Animal welfare.

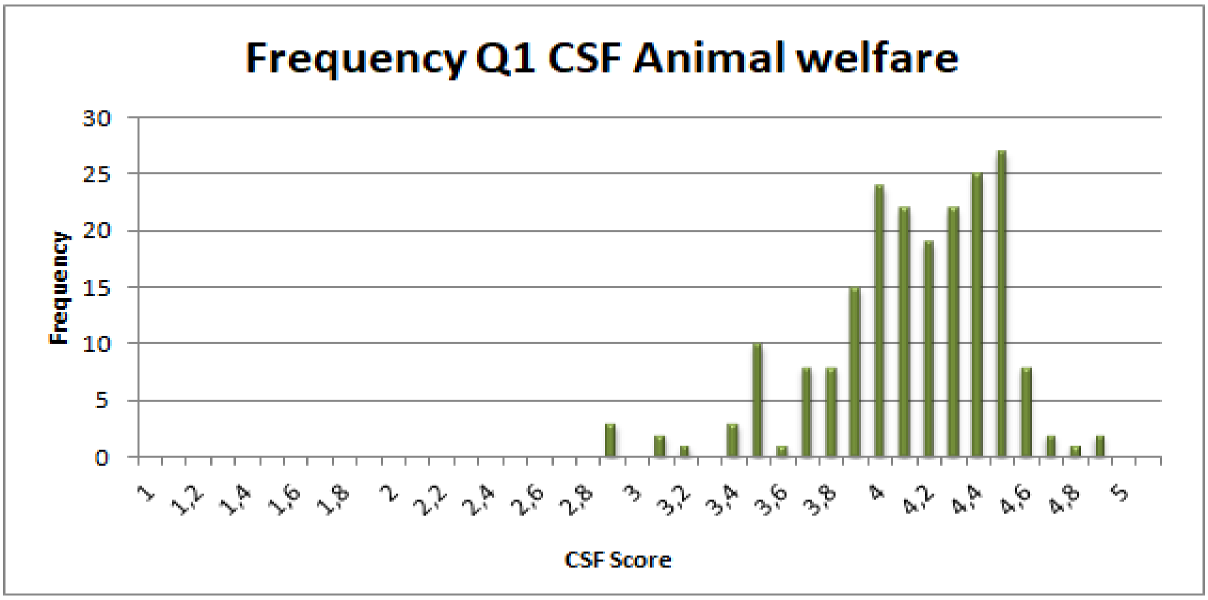


Figure 25. The frequency distribution of the first quartile (Q1) of the selected veterinarians for the Critical Success Factor (CSF) Animal welfare.

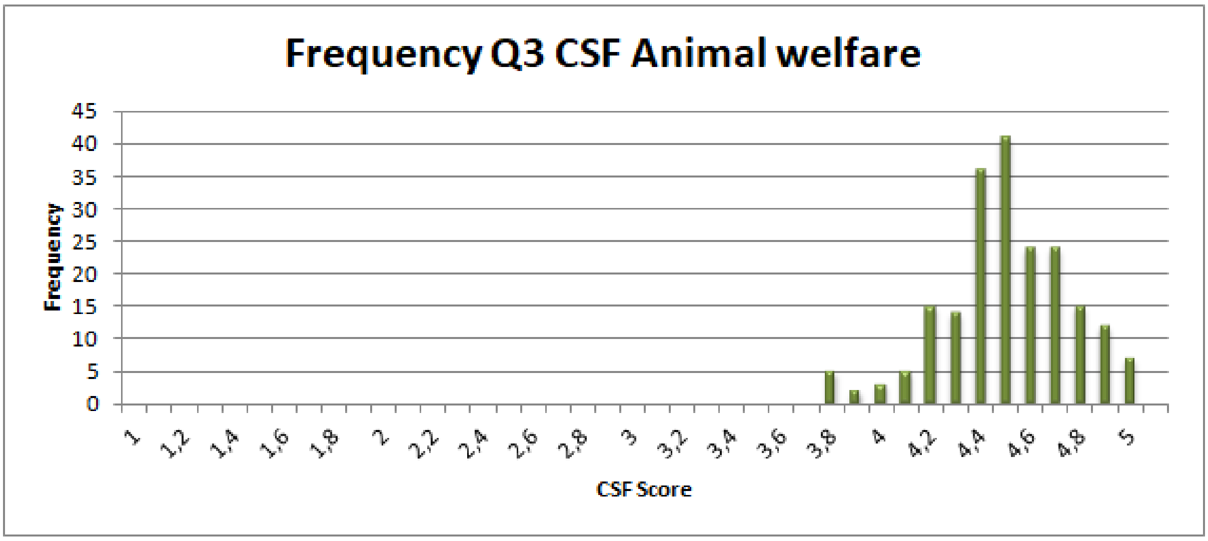


Figure 26. The frequency distribution of the third quartile (Q3) of the selected veterinarians for the Critical Success Factor (CSF) Animal welfare.

The spread width for the median is smaller within the CSF Work Routines, namely 1.5. The median varies from 3.0 to 4.5, Q1 from 2.7 to 4.2, and Q3 from 3.5 to 4.7. The CSF Animal Health shows a similar pattern as the median varies from 3.2 to 4.8. The Q1 of this CSF is 3.2 to 4.6, and the Q3 varies from 3.5 to 4.7. The range for the CSF Young Stock is greater, namely 1.8. The median varies from 3.0 to 4.8 (Figure 27), the Q1 from 2.7 to 4.5 (Figure 28) and the Q3 from 3.1 to 4.7 (Figure 29).

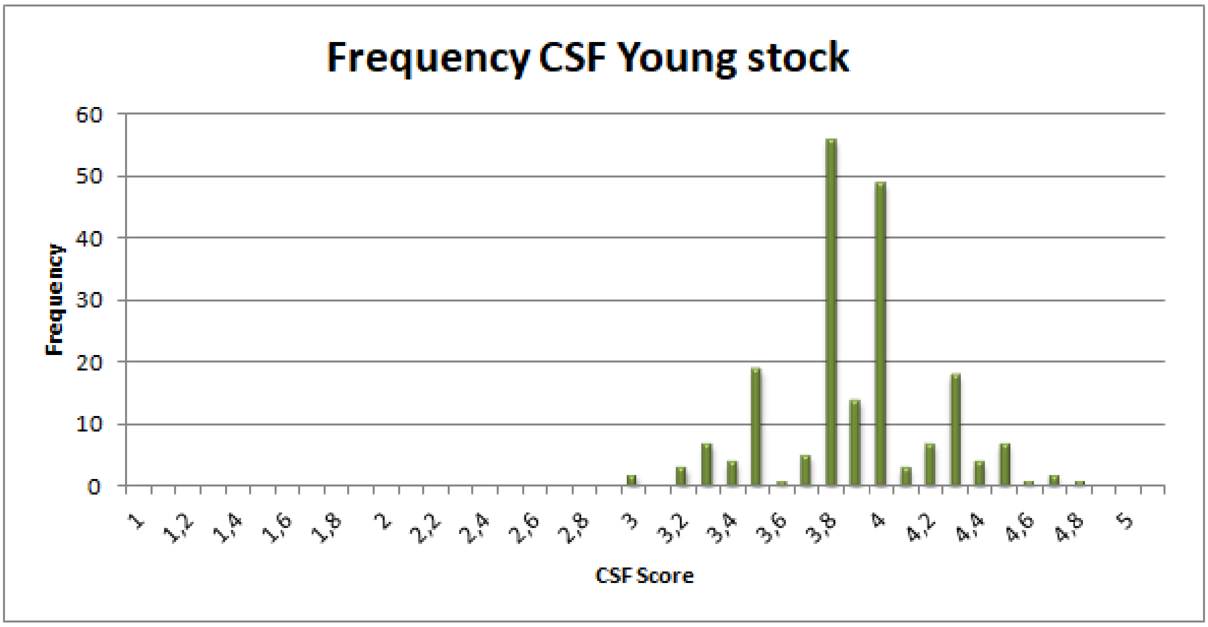


Figure 27. The frequency distribution of the median of the selected veterinarians for the Critical Success Factor (CSF) Young Stock.

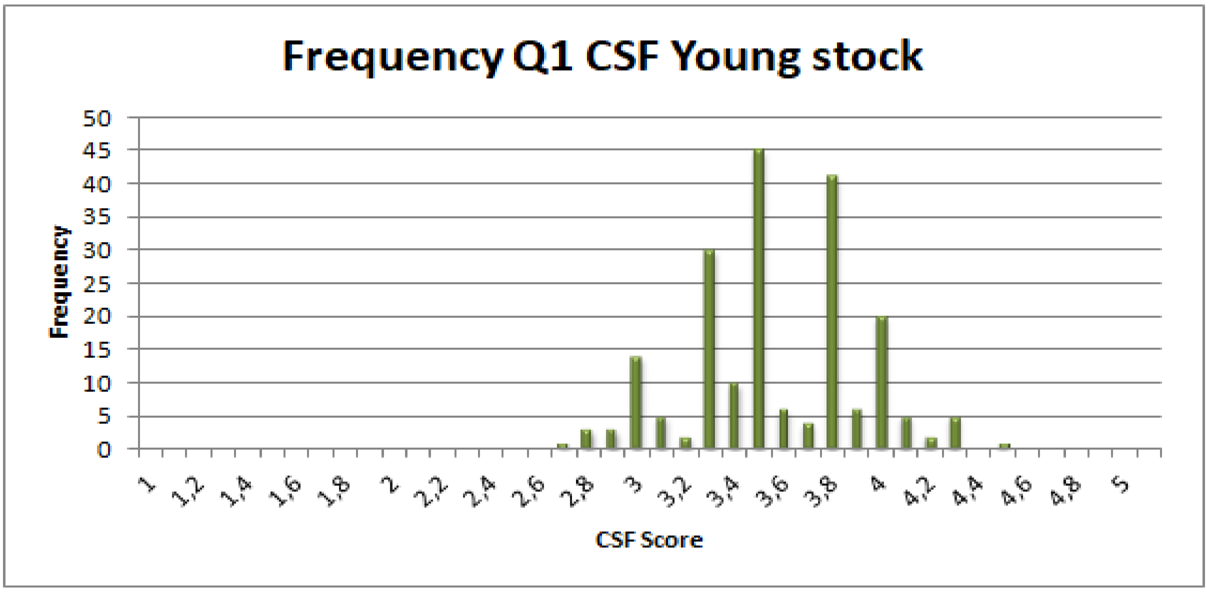


Figure 28. The frequency distribution of the first quartile (Q1) of the selected veterinarians for the Critical Succes Factor (CSF) Young Stock.

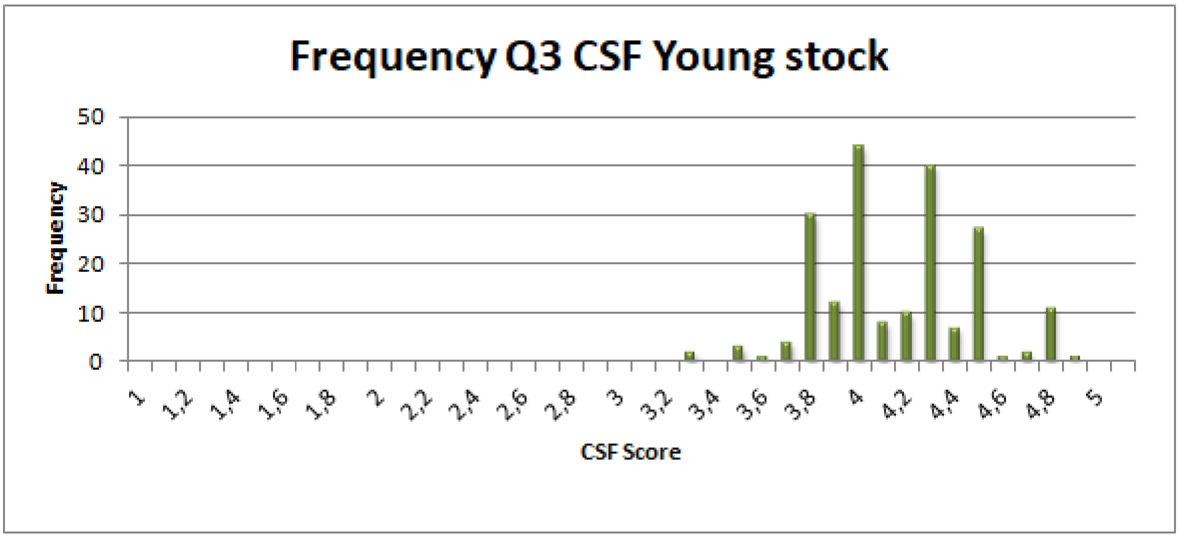


Figure 29. The frequency distribution of the third quartile (Q3) of the selected veterinarians for the Critical Success Factor (CSF) Young Stock.

Discussion

The repeatability of CowCompass has not been validated yet. To guarantee the quality of the CowCompass performed, an annual training is mandatory, resulting in certification of veterinarians. In this training a CowCompass that has already been released is analyzed in a smaller group in order to enhance the uniformity of scoring.

Benchmark design

Farmer benchmark

In addition to the benchmark for each CSF and PI, consideration was given applying a (weighted) average benchmark for the entire CowCompass. However, this is contrary to the primary goal of CowCompass: the identification of risks. If there would be an average score for the CFS, one could compensate for certain risks, and this would create a misplaced picture of the risks on the farm. Consideration was also given to correct the benchmark for farm size or production level, as this data is available in the data set. In consultation with the CowCompass Expert Board, it has been established that no distinction can be made for the scores achieved based on either the farm size or the production level. The reasoning is similar to the above: when analysing risks, no compensation based on farm size or production level may take place.

Veterinary benchmark

To compose a veterinary benchmark, a similar method was applied as for the farmers benchmark, as it is also based on frequency distributions. An important difference is the fact that the veterinarian generates multiple scores, since he (possibly) carries out a CowCompass on several farms. It is striking that 17% of the certified veterinarians carry out just one CowCompass. Only veterinarians who have performed a CowCompass on at least five different dairy farms are included in the analysis. If a veterinarian carries out less than this number, an unrepresentative view of this veterinarian may arise. It is possible that these are only high-risk or low-risk farms, as a result of which the veterinarian scores low or high, respectively. To reduce this bias in such a way, the current setup has been chosen. From the results it is striking that there is a large spread within the median, the first and third quartiles of the veterinarians. There are veterinarians where the first quartile of a certain CSF (for example CSF Housing and Husbandry) is a score of 5. This means that at least 75% of the scores generated at at least five different farms is a score of 5. After all, a score of 5 is the optimum score. In the case of the CSF Housing and Husbandry this is outstanding, since only 3% of the farmers achieve a score of 5 for this CSF. During this thesis, no specific benchmark has been drawn up for veterinarians, as there is currently no insight into the cause of the dispersion of veterinarians. On one hand, this dispersion can be caused by individual spread of the various dairy farms. In the Netherlands, there is a large spread in types and professionalism of dairy farms. This is often strongly region-specific, which may contribute to the spread of the veterinarians. On the other hand, there can be a spread in the individual assessment of the veterinarians. In other words, the veterinarians are possibly not uniform in the assessment of dairy farmers. It has already been mentioned that the repeatability of CowCompass at the time of this thesis has not been validated yet. Lack of uniformity of the veterinarians questions the objectivity of the certified veterinarians of CowCompass. In addition, it is still possible that certain veterinarians only guide high-risk companies, resulting in a lower score for these veterinarians. The question remains to what extent distribution in scores of veterinarians is a problem. The spread does not provide a good insight into the uniformity of the veterinarians. This can only be achieved by sending several veterinarians to one farm, and let them individually assess this farm. Further research into this uniformity is therefore indicated, and cannot be obtained from the current data set.

The interpretation of a benchmark for veterinarians is more complex compared to the benchmark for farmers. The score for the farmers is generated by the veterinarian, so the farmer is dependent on the veterinarian. The veterinarian's scores are generated by the veterinarian personally, so a veterinarian can generate a feasible score relatively easily. Within the CowCompass product, an objective and open view from the veterinarian must be pursued, which is not supported by such a benchmark based on feasibility. Due to the current dataset it is not possible to benchmark the certified veterinarians yet.

Established benchmark

Critical Succes Factor Milking

The data from CowCompass is mainly based on findings from the executive, certified veterinarian. However, the CSF Milking stems from the data supplied by the farmer. It is striking that the CFS Milking has the highest benchmark, 4.8 respectively. The CSF Milking takes stock of the risks related to the milking process, which have an effect on milk quality. Quality is essential for a food-producing chain (Yang *et al*., 2019), is partly legally determined (Regulation (EC) No 853/2004), and is therefore demanded by the various dairy companies. The quality of dairy companies is guaranteed both internally and externally. The high benchmark may be caused by this fact. Research by Meuwissen *et al*. (2001) shows that, according to Dutch livestock farmers, production risks are an important source of risk. Because the farmer is already aware of intensive controlling of the milk, and his role within the food-producing chain, extra attention will be paid to this CSF. In addition, milking method is an important risk factor in udder health (Elbers *et al*., 1997; Miltenburg *et al*, 2017), which has a negative effect on animal health and the economic results of the farm (Seegers *et al*., 2003; Halasa *et al*., 2007; Hogeveen *et al*., 2011). The CSF Milking is only based on the data supplied by the farmer, whereby the degree of objectivity can be questioned. The CowCompass Handbook states that the veterinarian must validate the data in order to guarantee objectivity. It is unknown to what extent this will actually be implemented.

So, it can be concluded that the risks with regard to milking and milk quality are small (with the exception of individual exceptions) due to current legislation and regulations, control from the dairy industry, and the awareness of the dairy farmer. However, the risks may be underestimated by the moderate objectivity of the farmer. Validation of the CSF Milking by the certified veterinarian is indicated.

Critical Succes Factor Feeding and Water

The farmer benchmark for the CSF Feeding and Water is set at 4.2. So, it can be concluded that this CSF is possibly a higher risk on the dairy farm. The percentage distribution per PI shows that in particular water quality (for both lactating and dry cows) and the feeding of dry cows are risky. However, in the case of water quality in lactating cows, the benchmark is set to a score of 5. This is due to the fact that 33% of farmers are able to achieve a score of 5. On the other hand, approximately 31% of the farmers achieve a score of 3 or lower. The PI water quality lactating cows therefore has some spread in terms of scores. A score of 4 or 5 can only be achieved if the quantity, accessibility, sediment, clarity and color meet the requirements set by the CowCompass Handbook. If the odor is insufficient, a score of 4 is obtained, if this is sufficient, the score of 5 is awarded. 31% of the farmers do not meet the requirements with regard to quantity, accessibility, clarity and color, so that a maximum score of 3 is awarded. The water quality of dry cows shows a similar trend in which 35% of the farmers have a score 3 or lower. The underlying water quality flow chart is the same for both animal groups. Water is seen as the most important nutrient for dairy cattle, whereby access to sufficient and clean drinking water is assessed as necessary. In addition, it is essential to prevent negative consequences for welfare, animal health and performance (Meyer *et al*., 2004). Metz *et al*. (2015) found that 96% of Dutch dairy herds (participated in the study) had free access to water. The requirements of the Handbook Dairy Farming 1997 (Vink and Wolberts, 1997) with regard to the number of drinking places and the capacity of these drinking places were met. In addition, drinking water was clean and fresh for 98% of dairy farms. The percentages of Metz *et al*.

(2015) are significantly higher compared to the results found in this study. This difference may be caused by the stricter requirements regarding water quality from the CowCompass Handbook (e.g. water flow rate).

Feeding dry cows is (possibly) a risk for dairy farms, as 36% of dairy farmers achieve a score of 3 or lower. The underlying feeding schedule is based on quantity, quality, and the suitability of the ration for the relevant group of animals (dry cows). In terms of percentage, all farmers achieve a score of 2 or higher. On the basis of the flow chart, which is shown in the CowCompass Handbook, it can be stated that the quantity and quality of the feed is in any case not insufficient. At virtually all dairy farms, with the exception of individual exceptions, there is at least a moderate amount of feed, which is reasonably distributed for the feeding fence. Little or no heating or mold is present here. 23% of dairy farmers score a 3, where the feed has a moderate to good quality, but is insufficiently suitable for dry cows. A score of 4 or 5 can only be achieved if the quantity and quality of the ration is good. In addition, it should fit moderately to well with the group. For 43% of the farmers the ration of the dry cows is moderately suitable and for 21% of the farmers the ration is well suited for dry cows. From the above it can be concluded that the risks within the PI feeding dry cows can be traced back to the quality of the feed and whether the ration is suitable for dry cows. The emphasis of the diet in the dry period is mainly on preparing the animal for the subsequent lactation (Friggens *et al*., 2005), whereby sufficient dry matter intake during this period is crucial (Grummer *et al*., 2004). Inadequate nutrition during the dry period has a major influence on the postpartum animal disease incidence (e.g. metabolic disorders, mastitis, etc.) (Cameron *et al*., 1998; Friggens *et al*., 2005) and therefore has a negative effect on animal health, and the economic results of the farm. Dry matter intake depends, among other things, on the quality and palatability of the product, with the quality of the roughage strongly dependent on the weather conditions (Wilkinson, 1981; Haigh, 1990). An incorrect assessment can result in heating or mold formation of the roughage, resulting in a lower PI and CSF score.

The CSF Feeding and Water has a wide range of scores and can therefore be labeled as risky. Within the CSF Feeding and Water the feed and water supply during the dry period is mainly risky, whereby the quality requirements set by the CowCompass Handbook are not met.

Critical Succes Factor Housing and Husbandry

The farmer benchmark for the CSF Housing and Husbandry is set at 4.0, and therefore has the lowest benchmark. This implies that this CSF has the highest risks. Within this CSF, the PI walking space and lying comfort have the highest risks, as respectively 65% and 49% of the farmers score 3 or lower. Within the PI walking space, 19% of the farmers score a score of 1 or 2, whereby the quantity (width of the walking space) and the quality of the flooring is moderate to insufficient and do not meet the requirements stated in the CowCompass Handbook. 4% of the participants of CowCompass do not score sufficiently on the quantity of the walking space. Here the walking area around the feeding fence is narrower than 3 meters (one or two rows of cubicles) or 3.5 meters (three rows of cubicles) and the walking area between the cubicles are narrower than 2.0 meters (one or two rows of cubicles) or 2.5 meters (three rows of cubicles). An exact comparison with other studies is complicated, due to the use of different guidelines for housing requirements. Trillo *et al*. (2017) found that for 64% of Spanish cattle farmers (participating in the study) the width of the walkway behind the feed fence was less than 4.2 meters. In addition, for 80% of its participants, the walkway between the cubicles was less than 3.5 meters. In his study, no distinction was made between the number of rows of cubicles, in contrast to CowCompass. Approximately 46% of the farmers score a 3, with the quantity and quality of the walking space being moderate to good, but flooring only consisting of concrete. Rubber is more animal-friendly and is therefore preferred (CowCompass Handbook).

Lying comfort is assessed for quantity (number), consistency, hygiene, dimensions of the cubicles and headroom. If a stable has ≤90% cubicles, a score of 1 is awarded. Approximately 1% of the farmers (N = 35) achieve this score. Cows are known to need adequate rest (around 12 hours a day). This behavior has a higher priority compared to foraging and social behavior (Grant, 2012). This implies the importance of sufficient cubicles. In addition, a clean, dry and comfortable cubicle is associated with a longer rest period, better animal health and an increase in productivity (Grant, 2012). The cow prefers a soft bedding (Grant, 2012; Declerck *et al*., 2012). A farm with 90-100% cubicles, but the hardness of the bedding is insufficient, a score of 2 is awarded. This is equivalent to 10% of the participants of CowCompass. 38% of the farmers score a 3, with the size of the cubicles being the limiting factor. The shortage of cubicles is possibly a result of the increase in scale that has taken place in recent years. In the year 2000 the average Dutch dairy farm consisted of 56 dairy cows and in 2016 this was 101 (Central Office of Statistics, 2017). This is an increase of 180%, whereby it is possible that this increase in scale has had a negative impact on the quantity of housing. Trillo *et al*. (2017) found an overcrowding of 32% among Spanish dairy farms. For 38% of the farms, the cubicle size is the limiting factor. The recommendations for cubicle sizes is a constantly changing process, depending on the size of the animals, which is constantly changing. Between 1991 and 2005, the height of the Holstein-Friesian cow increased one centimeter every two to three years (Declerck *et al*., 2012). The cubicle width that was advised in 2003 was 110 cm (Gaworski *et al*., 2003), such a width is now assessed as moderate (CowCompass Handbook). Finally, housing optimization is seen as a major investment, which means that this is often done in the longer term (Wemmenhove *et al*., 2009).

From the above it can be concluded that there is a large spread within the CSF Housing and Husbandry, and this CSF, given to the lower benchmark, can be defined as risky. The housing requirements are constantly changing, with the investment costs being higher compared to the other CSFs. Knowing this, this may lead to the lower benchmark. Nonetheless, high-quantity and high-quality housing is essential for animal welfare.

Critical Succes Factor Animal Welfare

The farmer benchmark for the CSF Animal Welfare has been set at 4.5. As a result, this CSF has the highest benchmark, apart from CSF Milking. Animal welfare plays an increasingly prominent role in food-producing animals, and is a point of attention for producers, industry and consumers alike. Animal welfare is seen as a priority for both dairy farmers and the dairy industry. Various studies show that the majority of dairy farmers want to guarantee good comfort and well-being for their animals. However, not all farmers invest in improving the welfare of the animals. Failure to implement these changes is often related to a lack of time and money (Robichaud *et al*., 2019).
The analysis shows that the PIs hock score and hygiene score are the most important risks within this CSF. Hock swelling and lesions have been associated with reduced well-being in several studies. The occurrence of such lesions is the result of repeatedly lying on a hard lying surface (Kielland *et al*., 2010; De Vries *et al*., 2015). This results in compression of the soft tissue between the lying surface and bony protrusions (e.g. tarsus), with a reduced perfusion of this tissue as a result (Kielland *et al*., 2010). The score for the PI heel swelling is based on the frequency of a certain hock score (ranging from score 1 to 5), which are shown in the CowCompass Handbook. The hock score with the highest frequency is the final score achieved for this PI. With a score of 4 or lower, there is a slight damage or discoloration present. Over the years, various studies have been conducted into the prevalence of hock lesions on dairy farms. This varies greatly between farms (Jewell *et al*., 2019; De Vries *et al*., 2015; Kielland *et al*., 2009), but is generally considered high (> 50%) (Kester *et al*., 2014). The same conclusion can be drawn from the current results, as 81% of the farmers participating in the CowCompass achieve a score 4 or lower.

Cow hygiene is seen as an important visual parameter for animal welfare (Vasseur, 2017), as dirt can cause infections and irritations (Hauge *et al*., 2012). In addition, it is used as an indicator for the hygiene of the stable and the bedding (Trillo *et al*., 2017), whereby good hygiene is essential for food safety (Hauge *et al*., 2012). The PI hygiene includes the contamination of udder, thighs and lower legs (including claws). Within the PI hygiene, 38% of the farmers achieve a score 3 or lower, 50% achieve a score 4 and 15% score a 5. This puts the benchmark for hygiene at 4. The scores are determined on the basis of a scorecard, whereby the frequency of a certain score at the farm determines the PI score. At 15% of the participating farms of CowCompass, mainly clean animals are observed. On the other farms, mainly slightly contaminated to heavily contaminated animals are observed. The bulk of the cow hygiene surveys takes place by scoring animals using a scoring system that differs between studies. In this context, individual hygiene of all animals is examined, rather than at farm level. Lombart *et al*. (2010) found that 49% of the animals achieved a good score. This percentage is significantly higher in comparison with the 15% determined in this study. The causes of reduced cow hygiene are extensive, and are often related to dirty bedding, insufficient comfort of the cubicles, dirty walking alleys or a dirty waiting room. In addition, a dirty tail can have a major impact. A dirty tail can be caused by a too thin consistency of manure (for example due to infectious diseases, a protein or OEB excess in the roughage, too large a percentage of concentrates in the ration, or too little structure in the ration) (Westerlaan *et al*., 2017). It has already been indicated for some of these causes that these risks are indeed present on dairy farms.

The PI's condition score and locomotion score do not have a benchmark, as the supplied data is not shown in a score from 1 to 5. For both the condition score and the locomotion score, the number of animals with a different score must be counted. This number of animals should be converted into a percentage of the entire herd. A score will be linked to this percentage (score 1 to 5). The database also contains numbers that exceed this score. The exact reason for this number is unknown, as it can be the number of animals, or the percentage of the number of animals. Due to lack of knowledge, it was decided not to analyze this data.

Given the high benchmark, the CSF Animal Welfare clearly has fewer risks compared to the other CSFs (with the exception of individual exceptions). Possibly, the current importance of good animal welfare results in the high score. Nevertheless, hock swelling or lesions can be observed in 80% of the farms. Hock lesions are an important welfare indicator, and indicate a reduced lying comfort. In addition, the hygiene of the animals is a risk, possibly with a reduced animal welfare and a higher animal disease incidence as a result. Despite the high benchmark, there are still risks within this CSF.

Critical Succes Factor Working Routines

The CSF Work Routines provide insight into animal health statuses, vaccinations, preventive measures, crossing lines of manure and feed, the specific treatment plan of the farm and grazing. The analysis shows that in particular the PI prevention and the PI crossing lines of manure and feed are risky, since 67% and 37% of the farmers achieve a score 3 or lower. The PI prevention includes an inventory of preventive measures within the business operations of the farm. The various measures include: separation of calf from cow after birth, provision of colostrum, provision of artificial milk, supply of cattle, separate roughage for young stock and contact between young stock and older cattle. Each measure is assessed by the veterinarian, and is then multiplied by the weighting (shown in the CowCompass Handbook). This results in a weighted average which is also the score for this PI. Partly due to this weighting, it is not possible to gain insight into the most important risks within this PI based on the current data set.

Critical Succes Factor Animal health

The CSF Animal health is based on the farmer's registration lists. The disease incidence of the past six months is automatically calculated back to an annual average. If the farmer does not registrate animal diseases, an estimate of the incidence is made in consultation with the farmer. If so, a maximum score of 3 can be achieved. The most important risks are high somatic cell counts, mastitis and claw problems. The literature shows that these are the most common animal diseases on dairy farms (Seegers *et al*., 2003; Van der Linde *et al*., 2010; Petersson-Wolfe *et al*., 2018).

The PI high somatic cell count inventories the percentage of animals with an increased somatic cell count. The term 'high somatic cell count' is applied if the somatic cell count for pluriparous cows is higher than 250.000 cells / ml and for heifers higher than 150.000 cells / ml. In addition to the individual animals, the bulk tank somatic cell count is also included in the assessment. The European Directive has determined that milk with a somatic cell count of 400.000 cells / ml may not be used for human consumption, so the bulk tank somatic cell count is used as a quality criterion (Lam *et al*., 2017). Approximately 37% of the farms achieve a score of 3 or lower. This implies that the bulk tank somatic cell count on these farms is at least 200.000 cells, and the percentage of animals with an increased somatic cell count varies from 20% to more than 30% (CowCompass Handbook, 2017). The national average bulk tank somatic cell count in 2017 was 172.000 cells / ml (Qlip, 2019) and the average percentage of cattle with an increased somatic cell count in the entire Dutch cattle population was 16% in 2016 (Lam *et al*., 2017). From this it can be concluded that 37% of the participants of CowCompass have a bulk tank somatic cell count above the Dutch average (2017) and the percentage of animals with a high somatic cell count is also above the Dutch average (2016). The somatic cell count is a measure of the number of inflammatory cells in the milk and is an indicator of udder infections. However, there is no direct relationship between the bulk tank somatic cell count and the incidence of clinical mastitis on the farm. It is known that the somatic cell count shows a seasonal pattern (Lam *et al.*, 2017). Lam *et al.* (2017) concluded a higher value in the compared to the winter months. In addition, the somatic cell count increases as lactation progresses and increases as the number of lactations increases. Udder infections nevertheless have the greatest effect on somatic cell count (Lam *et al*., 2017).

Current results show 30% of the participants of CowCompass achieve a score of 3 of lower for mastitis incidence. Hence, the incidence at these farms is at least 20%. 5% of the farms have an incidence more than 40%. The incidence of clinical mastitis in 2016 was less than 30% in the Netherlands (Lam *et al*., 2017). This is the case for 88% of the participants (score 3 or higher). The cause for an increased mastitis incidence is farm specific. Research has identified various risk factors, which are subdivided into different areas, including: housing and hygiene, feeding and water, dry period, vaccination, milking installation and milking method, and treatment (Lam and de Vlieger, 2017). Some risks have been discussed already within other CSFs, as risks have been found with regard to housing and hygiene (CSF Housing and Husbandry, and CSF Animal Welfare), and feeding and water during the dry period (CSF Feeding and Water). The presence of these risks may lead to a greater risk with regard to the development of mastitis.

These results show that a score of 3 or lower on PI claw problems is achieved on 39% of the participants of CowCompass. At these farms, the incidence of claw problems varies from 20% to more than 40%. The study by Gernand *et al*. (2012) found an incidence of 22.6% during lactation, where the incidents within CowCompass are based on six months. The prevalence of claw disorders in the Netherlands varies from 3% to 38%, with 69% of the animals having at least one claw disorder (Van der Linde *et al*., 2010). Similar prevalences were found in studies by other Dutch researchers (Somers *et al*., 2003; Van der Waaij *et al*., 2005). Within the PI claw problems, only incidence is taken into consideration, whereby this incidence is based on the registration lists of the farmer. The number of roofs per animal per year is not further discussed here. If only lame animals are trimmed, the current incidence may be an underestimation of the actual incidence. After all, an animal with a certain condition, of which it is not clearly lame, may not be trimmed. Or a lame animal may be missed. This is in great contrast to most studies, where the entire herd is normally trimmed.

Moderate hygiene of the animals is seen as a risk factor for an increased somatic cell count (Schreiner and Ruegg; 2003), and therefore an increased risk of intramammary infections (Trillo *et al*., 2017). Research shows that farmers with a bulk tank somatic cell count above 250.000 cells / ml have five times more often cows with a hygiene score 4, compared to farms with a bulk tank somatic cell count below 150.000 cells / ml. So, the somatic cell count is higher if more dirty cows are present (Westerlaan *et al*., 2017). In addition, moderate hygiene is associated with infectious disorders of the locomotive device (Fjeldaas *et al*., 2011). PI hygiene is considered to be risky and possibly also leads to the risks found within the CSF Animal Health.

With the current dataset it is not possible to gain insight into the registration lists of the farmers. As a result, it is unclear which part of the farmers actually register the animal disease incidence, and which proportion of the farmers score a maximum score of 3 due to not registering the incidence.

Critical Succes Factor Young Stock

The analysis shows that the most important risks for the CSF Young Stock are feeding and water, housing and husbandry, and the animal health. 36% of the farmers achieve a score of 3 or less for the PI feeding and water. This PI includes the period immediately after birth (colostrum intake), the period until weaning and the period after weaning. Every period can be assessed (if present) and a low score (risky) implies risks within these periods. Based on current data, it is not clear which period has the most risks. On one hand, a low score can be caused by inadequate provision of colostrum, but also suboptimal nutrition in weaned animals can lead to a score of 3. The provision of colostrum must be timely and sufficient, and the feeding and water must be of good quality and quantity (CowCompass Handbook).

Within the PI housing and husbandry of the young stock, 43% of the farmers achieve a score of 3 or less. During inventarisation of the stable, groups (age differences within the various groups), and grazing were analysed. A score of 3 can be generated if one or more of these parameters is assessed as moderate or insufficient (CowCompass Handbook).

Within the PI animal disease incidence, the incidence of diarrhea, lung problems, umbilical infections, parasitic diseases, calf mortality and ring scab are examined. A percentage distribution for each of these animal diseases is given in the CowCompass Handbook. On the basis of this distribution one can arrive at the relevant score. The data set only shows the 'final score' for this PI and not the scores per animal disease. As a result, no insight was obtained into the most important animal diseases in young cattle. It is known that the incidence of animal diseases in the first phase of life can be reduced through thorough hygiene, housing and nutrition. Hygiene during calving and adequate provision of colostrum is essential here (Mourits *et al*., 2009).

The exact risks within the various PIs of the CSF Young Stock cannot be assessed due to the current data set. Breeding young cattle is one of the most expensive processes on the dairy farm. The Dutch dairy farmer uses an average replacement percentage of 35%. Yet it appears that many dairy farmers underestimate the essence of good rearing of young cattle (Boersema *et al*., 2013).

Conclusion

The aim of this thesis was to investigate the possibility of benchmarking the data resulting from the CowCompass. The thesis provides an answer to the aforementioned research question and provides insight into the most important risks on dairy farms participating in CowCompass. It can be concluded that the data is indeed suitable for benchmarking, provided that the primary purpose of CowCompass (risk inventory) is taken into account. Benchmarking farmers based on feasibility is a good method to provide insight for farmers (and accompanying veterinarians) into their results compared to their colleagues. Such insight can stimulate and motivate to take Dutch dairy farming to an even higher level. The current data set is not suitable for benchmarking veterinarians. To benchmark the veterinarians, research into the spread within the veterinarians is indicated, as there is no insight in the uniformity of the veterinarians.

Reference

Boersema, JSC, Noordhuizen, JPTM, & Lievaart, JJ (2013). Hazard perception of Dutch farmers and veterinarians related to dairy young stock rearing. *Journal of dairy science*, *96*(8), 5027-5034.

Cameron, REB, Dyk, PB, Herdt, TH, Kaneene, JB, Miller, R., Bucholtz, HF, ... & Emery, RS (1998). Dry cow diet, management, and energy balance as risk factors for displaced abomasum in high producing dairy herds. *Journal of Dairy Science*, *81*(1), 132-139.

Centraal Bureau voor Statistiek (2017, 30 november). Schaalvergroting melkveehouderij maakt pas op de plaats. Geraadpleegd van https://www.cbs.nl/nl-nl/nieuws/2017/48/schaalvergroting-melkveehouderij-maakt-pas-op-de-plaats op 12-02-2019.

Declerck, I., Van Gansbeke, S., Opsomer, G., De Vliegher, S., de Kruif, A., & Maes, D. (2012). Enkele kritische punten bij de huisvesting van melkvee. *Vlaams Diergeneeskundig Tijdschrift*, *81*(3), 149-156.

De Vries, M., Bokkers, EAM, Van Reenen, CG, Engel, B., Van Schaik, G., Dijkstra, T., & De Boer, IJM (2015). Housing and management factors associated with indicators of dairy cattle welfare. *Preventive veterinary medicine*, *118*(1), 80-92.

Elbers, ARW, Miltenburg, JD, De Lange, D., Crauwels, APP, Barkema, HW, & Schukken, YH (1998). Risk factors for clinical mastitis in a random sample of dairy herds from the southern part of The Netherlands. *Journal of dairy science*, *81*(2), 420-426.

Elmuti, D., & Kathawala, Y. (1997). An overview of benchmarking process: a tool for continuous improvement and competitive advantage. *Benchmarking for Quality Management & Technology*, *4*(4), 229-243.

Fjeldaas, T., Sogstad, Å. M., & Østerås, O. (2011). Locomotion and claw disorders in Norwegian dairy cows housed in freestalls with slatted concrete, solid concrete, or solid rubber flooring in the alleys. Journal of dairy science, 94(3), 1243-1255.

Friggens, NC, Andersen, JB, Larsen, T., Aaes, O., & Dewhurst, RJ (2004). Priming the dairy cow for lactation: a review of dry cow feeding strategies. *Animal Research*, *53*(6), 453-473.

Gaworski, MA, Tucker, CB, Weary, DM, & Swift, ML (2003). Effects of stall design on dairy cattle behaviour. In *Fifth International Dairy Housing Conference for 2003* (p. 139). American Society of Agricultural and Biological Engineers.

Gernand, E., Rehbein, P., Von Borstel, UU, & König, S. (2012). Incidences of and genetic parameters for mastitis, claw disorders, and common health traits recorded in dairy cattle contract herds. Journal of dairy science, 95(4), 2144-2156.

Grant, R. (2012). Economic benefits of improved cow comfort. *Novus Int. St. Charles, MO*.

Grummer, RR, Mashek, DG, & Hayirli, A. (2004). Dry matter intake and energy balance in the transition period. *Veterinary Clinics: Food Animal Practice*, *20*(3), 447-470.

Haigh, PM (1990). Effect of herbage water-soluble carbohydrate content and weather conditions at ensilage on the fermentation of grass silages made on commercial farms. *Grass and Forage Science*, *45*(3), 263-271.

Halasa, T., Huijps, K., Østerås, O., & Hogeveen, H. (2007). Economic effects of bovine mastitis and mastitis management: a review. *Veterinary quarterly*, *29*(1), 18-31.

Handboek KoeKompas (2017). Stichting KoeKompas.

Hauge, SJ, Kielland, C., Ringdal, G., Skjerve, E., & Nafstad, O. (2012). Factors associated with cattle cleanliness on Norwegian dairy farms. *Journal of dairy science*, *95*(5), 2485-2496.

Hogeveen, H., Huijps, K., & Lam, TJGM (2011). Economic aspects of mastitis: new developments. *New Zealand veterinary journal*, *59*(1), 16-23.

Jewell, MT, Cameron, M., Spears, J., McKenna, SL, Cockram, MS, Sanchez, J., & Keefe, GP (2019). Prevalence of hock, knee, and neck skin lesions and associated risk factors in dairy herds in the Maritime Provinces of Canada. Journal of dairy science, 102(4), 3376-3391.

Kester, E., Holzhauer, M., & Frankena, K. (2014). A descriptive review of the prevalence and risk factors of hock lesions in dairy cows. *The Veterinary Journal*, *202*(2), 222-228.

Kielland, C., Ruud, LE, Zanella, AJ, & Østerås, O. (2009). Prevalence and risk factors for skin lesions on legs of dairy cattle housed in freestalls in Norway. *Journal of dairy science*, *92*(11), 5487-5496.

Kielland, C., Bøe, KE, Zanella, AJ, & Østerås, O. (2010). Risk factors for skin lesions on the necks of Norwegian dairy cows. *Journal of dairy science*, *93*(9), 3979-3989.

Lam, T., De Vliegher, S. (2017). Deel 4: Management. In *Handboek Uiergezondheid Rund* (pp. 155-265). Communication In Practice.

Lam, T., Sandman-Berends, I., Kamphuis, C., Schukken, Y., & de Vliegher, S. (2017). Het celgetal en andere mastitisindicatoren. In *Handboek Uiergezondheid Rund* (pp. 71-86). Communication In Practice.

LeBlanc, SJ, Lissemore, KD, Kelton, DF, Duffield, TF, & Leslie, KE (2006). Major advances in disease prevention in dairy cattle. *Journal of dairy science*, *89*(4), 1267-1279.

Lievaart, JJ, Noordhuizen, JPTM, Van Beek, E., Van der Beek, C., Van Risp, A., Schenkel, J., & Van Veersen, J. (2005). The Hazard Analysis Critical Control Point's (HACCP) concept as applied to some chemical, physical and microbiological contaminants of milk on dairy farms. A prototype. Veterinary Quarterly, 27(1), 21-29.

Lombard, JE, Tucker, CB, Von Keyserlingk, MAG, Kopral, CA, & Weary, DM (2010). Associations between cow hygiene, hock injuries, and free stall usage on US dairy farms. *Journal of dairy science*, *93*(10), 4668-4676.

Metz, JHM, Dijkstra, T., Franken, P., & Frankena, K. (2015). Development and application of a protocol to evaluate herd welfare in Dutch dairy farms. *Livestock Science*, *180*, 183-193.

Meuwissen, MP, Huirne, RBM, & Hardaker, JB (2001). Risk and risk management: an empirical analysis of Dutch livestock farmers. *Livestock production science*, *69*(1), 43-53.

Meyer, U., Everinghoff, M., Gädeken, D., & Flachowsky, G. (2004). Investigations on the water intake of lactating dairy cows. *Livestock production science*, *90*(2-3), 117-121.

Miltenburg, JDHM, Scherpenzeel, CGM, Lam, TJGM Lam. (2017). Melker en Melken. In T. Lam en S. De Vlieger (Red.), Handboek Uiergezondheid Rund (pp. 237-250). Nijmegen, Nederland: Communication in Practice.

Noordhuizen, JPTM, & Metz, HM (2005). Quality control on dairy farms with emphasis on public health, food safety, animal health and welfare. *Stočarstvo: Časopis za unapređenje stočarstva*, *59*(1), 39-55.

Petersson-Wolfe, CS, Leslie, KE, & Swartz, TH (2018). An Update on the Effect of Clinical Mastitis on the Welfare of Dairy Cows and Potential Therapies. *Veterinary Clinics: Food Animal Practice*, *34*(3), 525-535.

Qlip. Celgetal zet opnieuw stap voorwaarts. Geraadpleegd van https://www.qlip.nl/nl/actueel/580-celgetal-zet-opnieuw-stap-voorwaarts op 30-03-2019.

Robichaud, MV, Rushen, J., de Passillé, AM, Vasseur, E., Haley, D., & Pellerin, D. (2019). Associations between on-farm cow welfare indicators and productivity and profitability on Canadian dairies: II. On tiestall farms. *Journal of dairy science*.

Schreiner, DA, & Ruegg, PL (2003). Relationship between udder and leg hygiene scores and subclinical mastitis. Journal of dairy science, 86(11), 3460-3465.

Seegers, H., Fourichon, C., & Beaudeau, F. (2003). Production effects related to mastitis and mastitis economics in dairy cattle herds. *Veterinary research*, *34*(5), 475-491.

Somers, JGCJ, Frankena, K., Noordhuizen-Stassen, EN, & Metz, JHM (2003). Prevalence of claw disorders in Dutch dairy cows exposed to several floor systems. *Journal of dairy science*, *86*(6), 2082-2093.

Trillo, Y., Quintela, LA, Barrio, M., Becerra, JJ, Peña, AI, Vigo, M., & Herradon, PG (2017). Benchmarking welfare indicators in 73 free-stall dairy farms in north-western Spain. Veterinary record open, 4(1), e000178.

Van der Linde, C., De Jong, G., Koenen, EPC, & Eding, H. (2010). Claw health index for Dutch dairy cattle based on claw trimming and conformation data. *Journal of dairy science*, *93*(10), 4883-4891.

Van der Waaij, EH, Holzhauer, M., Ellen, E., Kamphuis, C., & De Jong, G. (2005). Genetic parameters for claw disorders in Dutch dairy cattle and correlations with conformation traits. *Journal of Dairy Science*, *88*(10), 3672-3678.

Vasseur, E. (2017). ANIMAL BEHAVIOR AND WELL-BEING SYMPOSIUM: Optimizing outcome measures of welfare in dairy cattle assessment. Journal of animal science, 95(3), 1365-1371.

Vink, I., Wolbers, H., 1997. Handboek Melkveehouderij. Praktijkonderzoek Rundvee, Schapen en Paarden. PR-Lelystad. Wageningen University, Wageningen, p. 520.

Wemmenhove, H., Biewenga, G., Ouweltjes, W., & Verstappen, J. (2009). Brochure Moderne huisvesting melkvee 7.

Westerlaan, B., Maes, D., Lam, T. (2017). Huisvesting en hygiëne. In *Handboek Uiergezondheid Rund* (pp. 155-168). Communication In Practice.

Wilkinson, JM (1981). Losses in the conservation and utilisation of grass and forage crops. *Annals of applied biology*, *98*(2), 365-375.

Yang, Y., Huisman, W., Hettinga, KA, Liu, N., Heck, J., Schrijver, GH, ... & van Ruth, SM (2019). Fraud vulnerability in the Dutch milk supply chain: Assessments of farmers, processors and retailers. *Food control*, *95*, 308-317.

Appendix

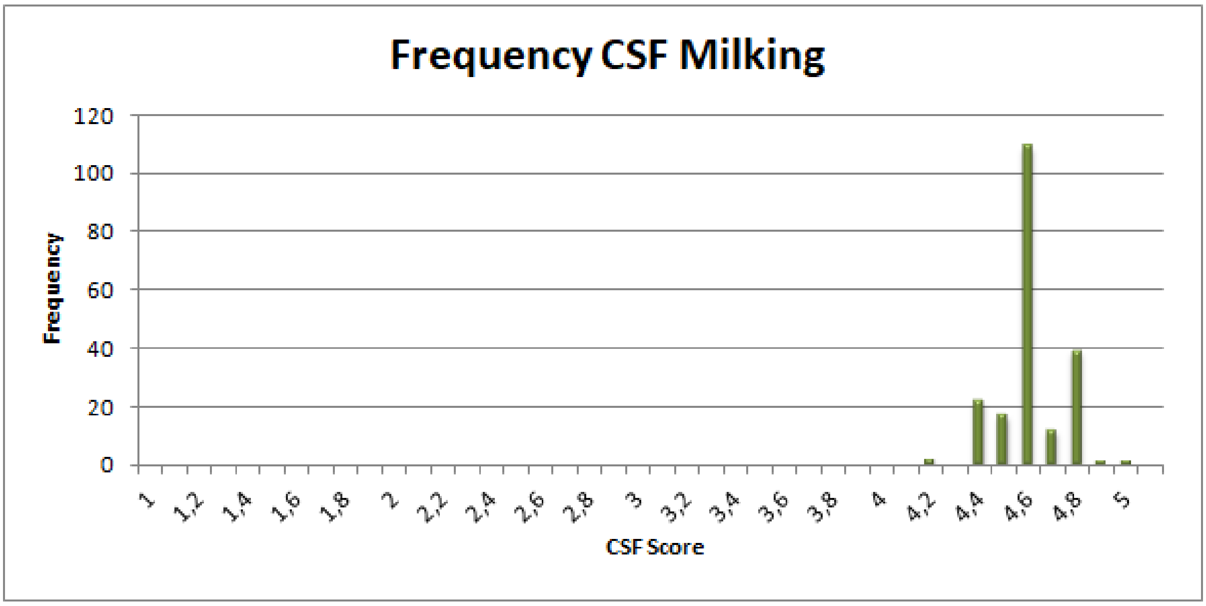


Figure A1. The median frequency distribution of the selected veterinarians for the Critical Success Factor (CSF) Milking.

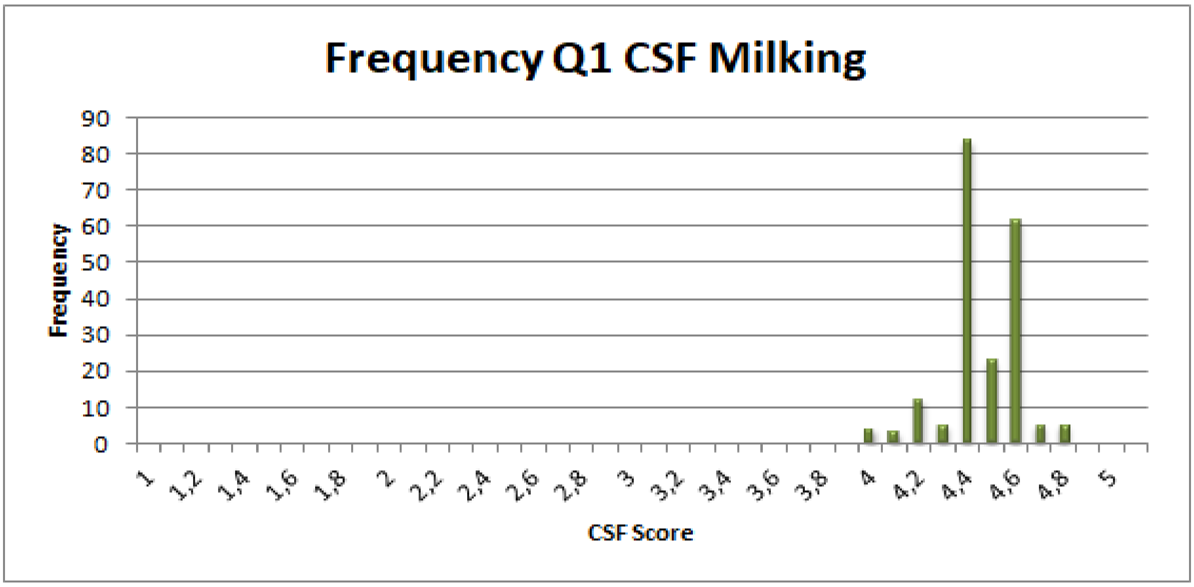


Figure A2. The frequency distribution of the first quartile (Q1) of the selected veterinarians for the Critical Success Factor (CSF) Milking.

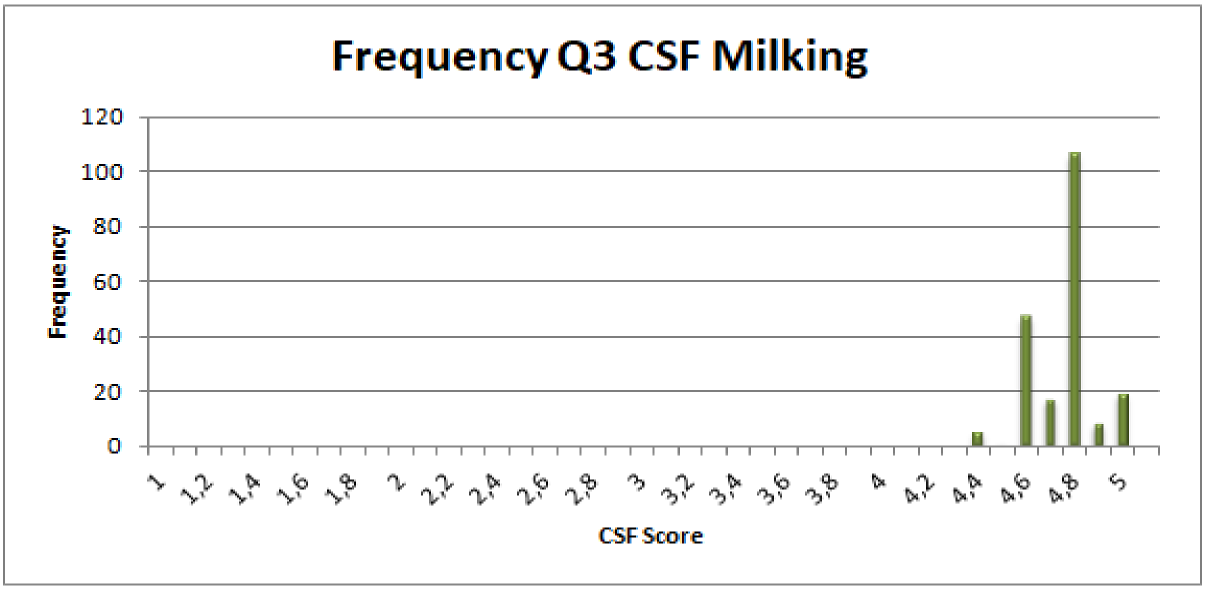


Figure A3. The frequency distribution of the third quartile (Q3) of the selected veterinarians for the Critical Success Factor (CSF) Milking.

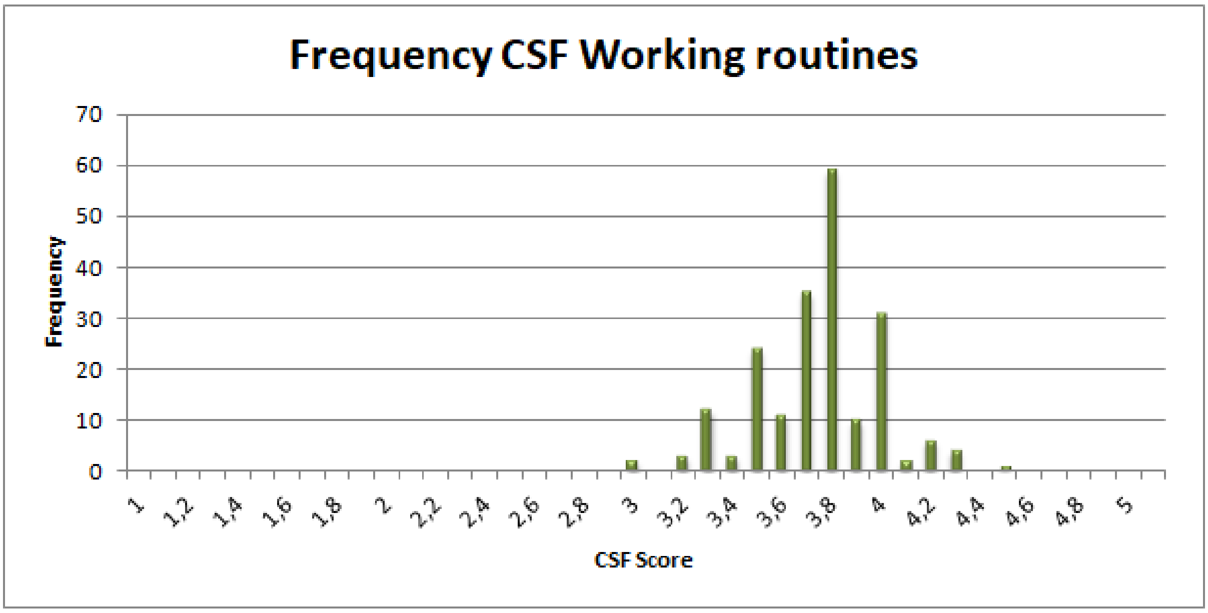


Figure A4. The median frequency distribution of the selected veterinarians for the Critical Success Factor (CSF) Working Routines.

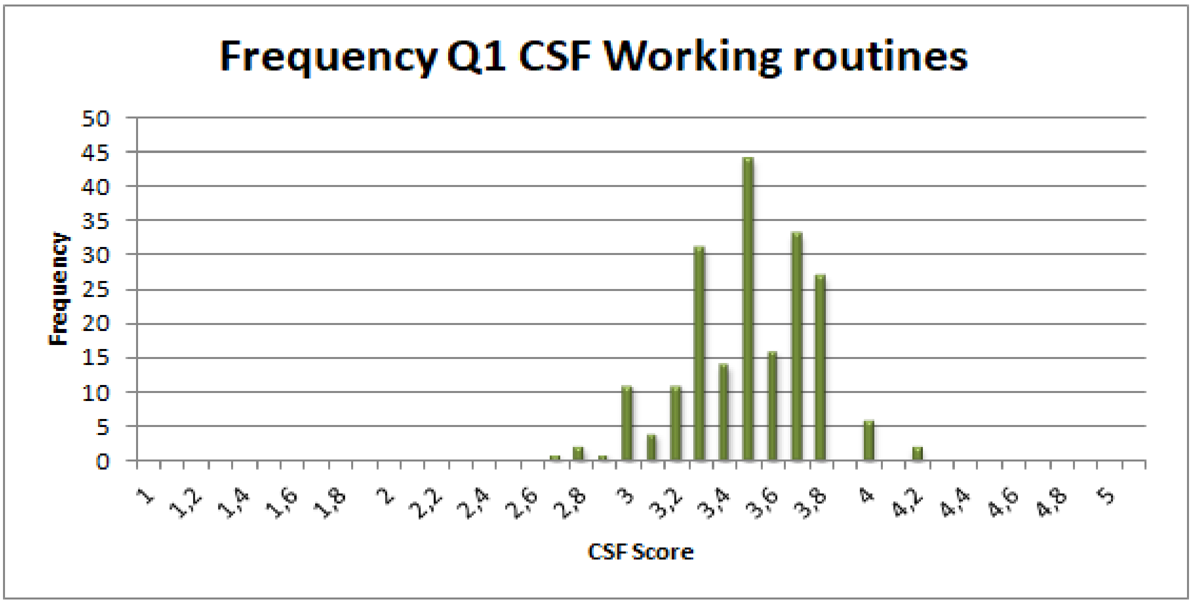


Figure A5. The frequency distribution of the first quartile (Q1) of the selected veterinarians for the Critical Success Factor (CSF) Working routines.

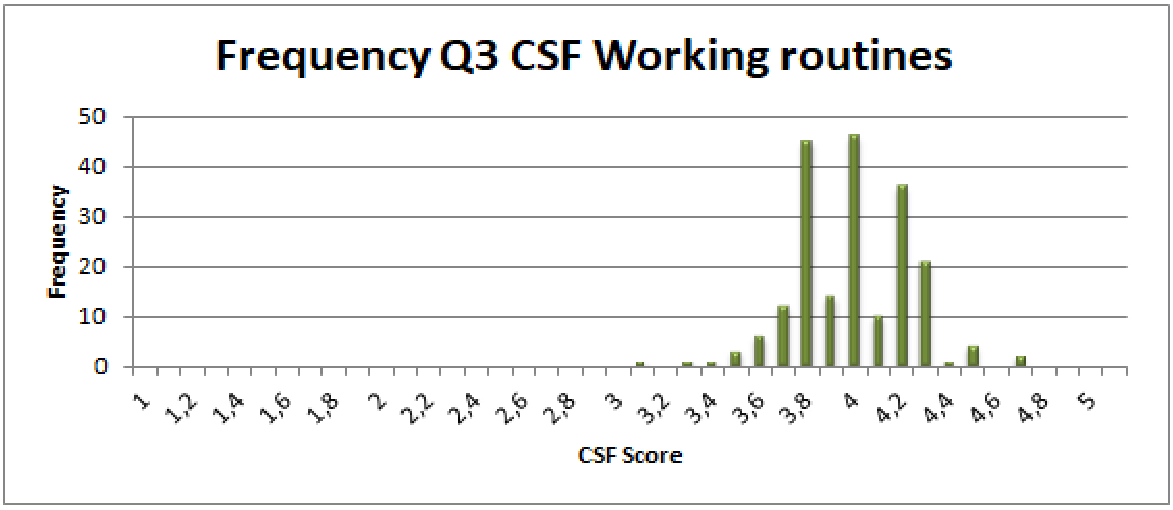


Figure A6. The frequency distribution of the third quartile (Q3) of the selected veterinarians for the Critical Success Factor (CSF) Working routines.

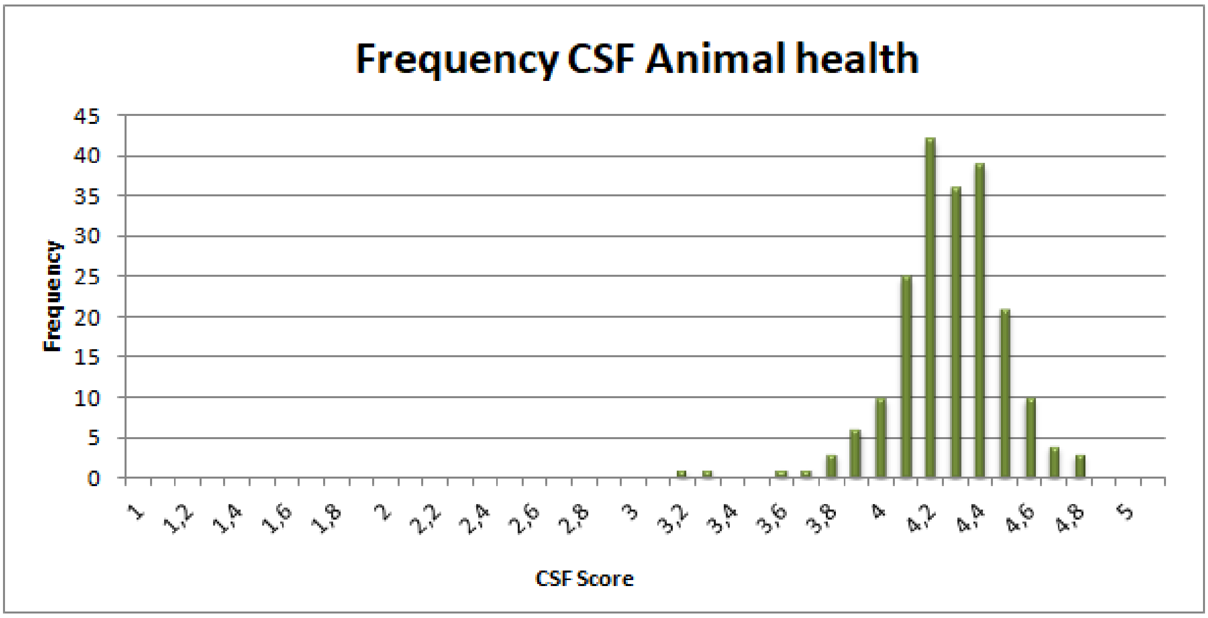


Figure A7. The median frequency distribution of the selected veterinarians for the Critical Success Factor (CSF) Animal health.

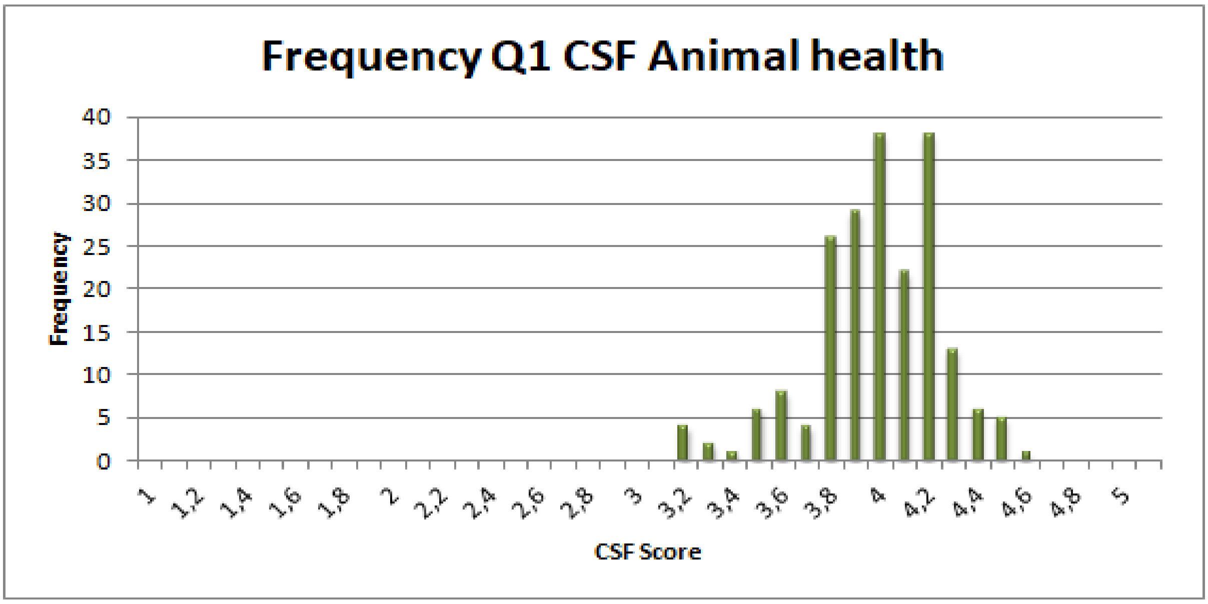


Figure A8. The frequency distribution of the first quartile (Q1) of the selected veterinarians for the Critical Success Factor (CSF) Animal health.

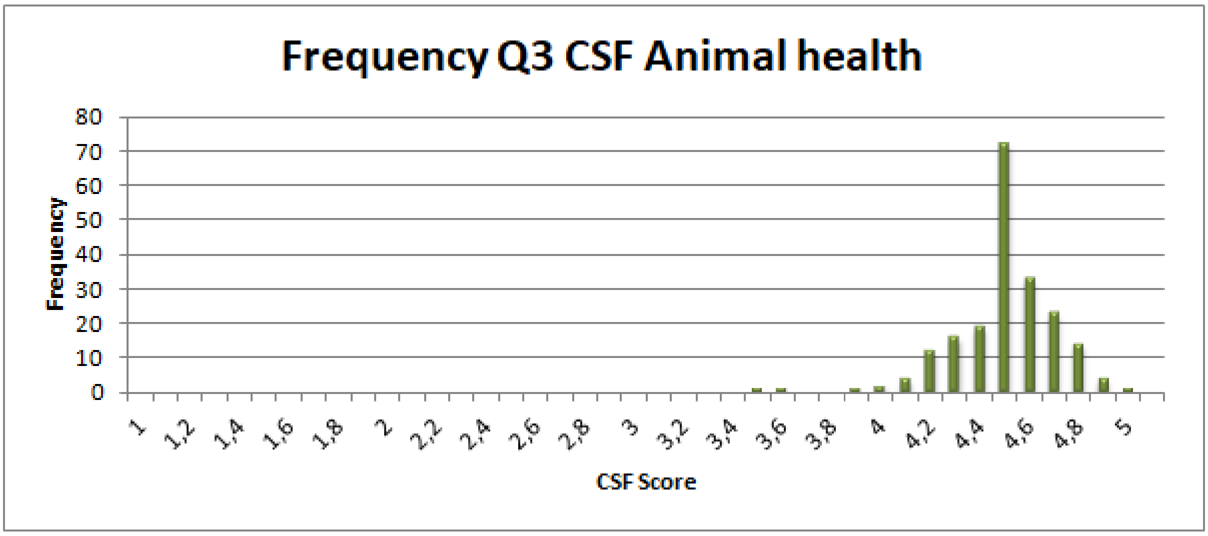


Figure A9. The frequency distribution of the third quartile (Q3) of the selected veterinarians for the Critical Success Factor (CSF) Animal health.