# Devices used by automated milking systems are similarly accurate in estimating milk yield and in collecting a representative milk sample compared with devices used by farms with conventional milk recording

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# Devices used by automated milking systems are similarly accurate in estimating milk yield and in collecting a representative milk sample compared to devices used by conventional milk recording

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**ABSTRACT**.

Information on accuracy of milk sampling devices used on farms with automated milking systems (**AMS**) is essential for development of milk recording protocols. Thy hypotheses of this study were: (1) devices used by AMS units are similarly accurate in estimating milk yield and in collecting representative milk samples compared to devices used by certified milk recording providers on farms with conventional milking systems (**CMS**) and (2) devices used on both AMS and CMS comply with accuracy criteria described by New Zealand Standard and by the International Committee of Animal Recording (**ICAR**). Milk recording data from five AMS farms were collected during 13 milk recording test days between December 2011 and February 2013. Milk yield was estimated by ICAR approved milk meters on AMS units. Milk samples were collected over a 48 h period and submitted to an off-site certified laboratory for milk composition analysis. Data were also collected manually from five to ten cows per AMS unit; a cow's complete milking was weighed to serve as gold standard for milk yield and three milk samples per cow milking were collected and analyzed in the laboratory to serve as gold standards for milk composition. A similar procedure was used during six milk recording occasions with devices used during conventional milk recording at a CMS research farm. Farm type, breed, season and region did not appear to affect accuracy of devices used on AMS units. Milk meters used by AMS units complied with ICAR limits in 12.5% and 25% of the milk recording test days for test bucket weights between 2-10kg and for test bucket weights >10kg, respectively. These percentages were 52% and 42%, respectively, for devices used on CMS. Analyzing all samples as one milk recording testy day, 1.4% fell outside the 20% difference band for AMS compared to 1.1% of the milk samples for CMS. Devices used by AMS complied with ICAR in 73% of the milk recording test days for fat percent, compared to 42% of the milk recording test days by devices used at CMS farm. When analyzing all milk samples as one milk recording test day, 3.5% of the milk samples fell outside the 99% ICAR limit for AMS compared with 17.2% of the milk samples for CMS. Applying the ICAR standards for fat percent to crude protein percent and SCC, devices used on AMS were accurate in estimating crude protein percent but not in estimating SCC. Thus, devices on AMS units did not comply with national nor ICAR standards with regard to milk yield and fat percent. However, devices used on AMS were similarly or more accurate compared to devices used during conventional milk recording. It is proposed that devices used on AMS units, when calibrated regularly and when set up according to the manufacturer's instruction, have similar or improved accuracy compared to CMS devices. Since the New Zealand industry accepts data from devices currently used by certified providers for milk recording on CMS farms, results imply that the AMS devices should also be permitted to be used for milk recording.

**Key words:** robotic milking, milk recording data, milk sampling devices, accuracy

## INTRODUCTION

Robotic or automated milking systems (**AMS**) were introduced in 1992 (Bottema, 1992). Adoption of this technology was slow at first (De Koning, 2010) and initially took place in countries with high yielding cows, high milk prices, high labor costs and family-run farms (Lind et al., 2000). Adoption rates increased from the year 2000 onwards (De Koning, 2010) and included countries with lower-input pasture-based dairying systems (e.g., Jago et al., 2004). As of today, it is estimated that well over 10,000 farms worldwide use one or more AMS units to milk their herd (Rodenburg, 2013). One of the key characteristics of AMS is that the cow herself initiates the milking and, thus, milking intervals vary within and between cows.

Milk recording data is valuable for farmers to make management decisions regarding feeding, reproduction and culling. For breeding companies, milk recording data are essential to identify sires and cows that will contribute to the genetic gain of future generations of dairy cattle. Collecting milk recording data on farms with conventional milking systems (**CMS**), where cows are milked as one batch with more or less fixed milking intervals (e.g., in herringbones and rotary parlors), is clearly defined in milk recording standards. Farms with CMS are often offered flexible options in terms of collecting milk recording data, including the frequency of milk recording (from one to twelve week intervals), full and/or alternate milk recording, and supervised or unsupervised milk recording (Miglior et al., 2002). However, standards generally lack protocols for collecting milk recording data from systems where cows in the herd are milked 24 h per day and where milking intervals may vary between and within cows, as is the case in AMS. As a consequence, different countries apply different methods to collect and handle milk recording data from AMS farms (Miglior et al., 2002).

In New Zealand, milk recording standards were developed before AMS technology was an option. Therefore, the standards only allow submission of milk recording data into the national database from herds that are milked in CMS. As a consequence, New Zealand farmers that currently use AMS (n = 15 herds; J. Jago, DairyNZ Ltd., Newstead, Hamilton 3240, New Zealand, personal communication) are unable to submit milk recording data. A protocol for collecting milk recording data on AMS farms in New Zealand has been suggested by Jago and Burke (2013). This protocol involved the automated collection of milk samples of every cow milked by the AMS units during a 48 h time-period. While Jago and Burke (2013) suggested that their applied 48 h sampling period may be reduced to 24 h, to be accepted by New Zealand milk recording standards, validation of the approach described in the 48 h protocol was essential. This validation required data from AMS farms representing a variety of milking frequencies and typically representative of farms that varied in intensity (e.g., pasture-based low supplementary feed input vs. housed high supplementary feed input dairy systems), breeds, season, and region. Part of the validation involved assessing the accuracy of the milk meters in estimating milk yield and of the automatic milk sampling devices used to collect a representative sample of a cow's complete milk. The accuracy of these milk meters and the automatic milk sampling devices should meet the accuracy criteria described in the New Zealand Standard (2007) and preferably also the standards described by the International Committee of Animal Recording (ICAR, 2012).

The hypotheses of this study were: (1) milk sampling devices (milk meters and automatic milk sampling devices) used on AMS units are similarly accurate in estimating milk yield and in collecting a representative milk sample compared to devices used by certified milk recording providers on CMS farms and (2) milk sampling devices used on AMS and CMS comply with accuracy criteria described by the New Zealand Standard (2007) and by ICAR (2012).

## MATERIALS AND METHODS

Data used for this study originated from two separate but parallel running studies and, therefore, will be described in two separate sections.

### *Data Collection from Farms with Automated milking systems*

Data were collected between December 2011 and February 2013 at five New Zealand farms located in the North (n = 2) and South Island (n = 3). The two main AMS suppliers in New Zealand were represented with two farms using a total of six DeLaval units (from the 2010 model with ICAR approved milk meters; DeLaval International AB, Tumba, Sweden) and the remaining three using Lely units (Lely Industries NV, Rotterdam, The Netherlands; eight A3-units with a jar-type milk meter system and six A4-units with load-cells to estimate milk yield; both milk meter devices were ICAR approved). The selected farms represented a range of New Zealand farm systems of varying herd sizes and breeds, including one farm milking a Jersey herd, one farm milking a Holstein-Friesian herd and the others milking predominantly Friesian and Friesian-Jersey crossbred cows (Table 1). The total number of milk recording test days conducted was 13, ranging between one and five milk recording test days per farm (Table 1).

Before the start of each milk recording test day, one of the AMS suppliers confirmed that AMS units and milk sampling devices used for milk recording were installed and conformed to operational specifications. This included the installation of an automatic milk sampling device to each AMS unit on farm by a representative of the AMS supplier or by a trained representative of the local farm service center. For the other supplier of AMS, farmers were responsible for the installation of the automatic milk sampling device and testing that they were operational before milk recording started. Automatic milk sampling devices collected milk samples into vials similar to those used by one of two certified providers for milk recording on CMS farms. Vials were pre-loaded with three drops of a 10% solution of the preservative Bronopol (BP2000, Chemiplas, Auckland, NZ) and stayed uncapped to allow the preservative to dry, requiring no volume adjustments when milk samples were analyzed for milk composition.

Each milk recording test day was conducted according to the 48 h protocol described by Jago and Burke (2013). This involved continuous data collection from the AMS management system (Process 1, Figure 1), including identification numbers of the AMS unit, the automatic milk sampling device and the cow, date and time of each cow milking, date and time of the previous milking of that same cow, milking interval as the time difference between current and previous milking, milk yield as recorded by the milk meters installed on each AMS unit, and whether or not the current milking had been successful according to

AMS software. During milk recording, automatic milk sampling devices collected a 25 mL milk sample from every cow milking over a 48 h time period (Process 2, Figure 1). Full vials were capped manually and recorded with a unique number, identifying the order in which the milk samples were collected and later used to match with data from the AMS management system. The full vials were removed from the automatic milk sampling device at regular intervals, replaced with empty ones, transferred into a sample tray (Sample Tray I; Figure 1) and refrigerated at 4°C until transported to the laboratory.

In addition to the automated collection of milk samples, trained DairyNZ research technicians manually collected three reference milk samples from each of five to ten cows per AMS unit during each milk recording test day between 7 a.m. and 10 p.m. (Process 3, Figure 1). To collect the three reference samples, AMS units were programmed to divert all milk into a test bucket after a cow finished milking. This test bucket was weighed before and after the milk was collected to estimate total milk yield for that cow milking, including an adjustment to account for the 25 mL of milk collected by the automatic milk sampling device. The test bucket milk was mixed and subsampled manually to collect the three reference milk samples (Process 3, Figure 1) using similar vials, pre-loaded with preservative, as used by the automatic milk sampling devices. The three reference milk samples were transferred to a second sample tray together with their corresponding sample collected by the automatic milk sampling device (Sample Tray II, Figure 1) and refrigerated at 4°C until transportation to the laboratory. The manually sampled cows included at least one high producing cow, one low producing cow, one cow with a high milking frequency, one with a low milking frequency and one randomly selected cow. Farm-specific performance indicators (e.g., milk yield and number of milkings per day) were used to identify these manually sampled cows.

Both sample trays (Sample Tray I and II, Figure 1) were sent to Testlink Laboratory (located in Hamilton, New Zealand, for milk samples collected in the North Island and in

Christchurch, New Zealand, for milk samples collected in the South Island) for milk composition analysis including fat and crude protein percent and SCC. Milk samples in Sample Tray II (Figure 1) were analyzed twice: following the first analysis, the tray was retained until the results were printed. The tray was then tested again through the same machine and the second set of results was generated. Results from the first and second analysis of Sample Tray II were used in the current study for the milk samples collected manually (six milk composition results). Results from the first milk composition analysis only were used for the milk sample that was collected by the automatic milk sampling device of that same cow-milking (Process 3; Figure 1).

***Data Collection from a Conventional Milking System***

Data were collected at DairyNZ's Lye Research Farm (Newstead, Hamilton 3240, New Zealand). Forty Friesian and Friesian-Jersey crossbred cows were selected from the entire herd to provide a sub-herd with a representative range of milk yields and SCC levels. The cows were managed as a single herd and milked twice daily using an 8-bail herringbone parlor. A re-familiarization period of eight milkings enabled the cows, normally milked in a rotary parlor, to get accustomed to milking in the small herringbone parlor.

Milk recording test days were conducted by two providers certified for milk recording (CRV Ambreed, PO Box 176, Hamilton 3240, New Zealand; LIC, Private Bag 3016, Hamilton 3240, New Zealand). Temporary installation of the milk sampling devices were completed by a certified provider's representative using routine procedures for milk recording on CMS farms. Each certified provider collected milk recording data on three occasions (early, peak and late lactation) in the 2012/2013 milking season. Each milk recording occasion comprised four consecutive milkings, equal to two consecutive milk recording test days each starting with the first milk sample collected at a p.m. milking. Milk samples collected by the certified provider's representative were weighed by DairyNZ technicians (Process 1; Figure 2). These samples were then split into one to five pre-loaded vials, depending on the volume of the collected milk sample, and stored in a sample tray (Sample Tray 1; Figure 2) refrigerated at 4°C until transportation to the laboratory. During each milk recording occasion, cows were milked into test buckets at every milking session using the same principle as with AMS systems; the test bucket was weighed before and after the milk was collected to estimate milk yield for that specific milking for that cow, including adjustment for the milk sample collected by the certified provider's representative. The test bucket milk was mixed and subsampled manually to collect four reference milk samples using pre-loaded vials similar to those used with AMS (Process 2; Figure 2). The reference milk samples were transferred into the same sample tray as milk samples collected from the certified provider's milk sample (Sample Tray 1; Figure 2). All milk samples were analyzed twice for milk composition by the TestLink Laboratory (Hamilton, New Zealand) using the same procedure as used for the AMS. Results from the first run only were used in the current study, including four milk composition results for each cow-milking that was manually collected (Process 2; Figure 2) and one to five milk composition results from the milk sample that was collected by the milk sampling device used by the certified providers (Process 1; Figure 2).

Before the current study commenced, certified providers were requested to install the milk sampling devices as used in the field without any special preparations. One certified provider, however, did calibrate these devices specifically for this study.

***Accuracy of Milk meters (AMS) and Milk Sampling Devices (CMS) in Assessing Milk Yield***

The accuracy of milk meters used in AMS and milk sampling devices used in CMS were assessed using accuracy standards described in Section 11 of ICAR (2012) and Appendix D of the New Zealand Standard (2007). According to ICAR (2012), the standard deviation and the bias of the estimated yield should be within 0.5 kg and 0.2 kg, respectively, for reference yields between 2-10 kg and less than 5% and 2%, respectively, for reference yields >10 kg. Appendix D of the New Zealand Standard (2007) states that 95% and 99% of the milk yield estimations must be within ±15% and ±20%, respectively, of the reference milk yield. In the current study, milk yield estimation refers to the yield assessed by the in-line milk meter on the AMS units and recorded by the herd management software (Process 1; Figure 1) or by the milk yield estimation derived from samples taken by the milk sampling devices used by the two certified providers (Process 1; Figure 2). The reference yield refers to the milk yield assessed by manual weighing of test buckets, adjusted for milk collected by certified providers at CMS (Process 2; Figure 2) and the 25 mL milk sample collected by the automatic milk sampling devices at AMS farms (Process 3; Figure 1). One AMS supplier recorded milk yield in liters and, therefore, results were converted to kilograms by multiplying the recorded milk yield by 1.03.

***Accuracy of Milk Sampling Devices in Collecting Representative Milk Samples***

Appendix D of the New Zealand Standard (2007) sub-sampling requirements for milk components state analyses to be applied to fat percent only and require 95% and 99% of all milk samples to be within ±0.1% and ±0.2% of the mean of the two reference samples, respectively. These requirements are more rigorous than those stated in ICAR (2012). Moreover, these accuracy requirements for sub-sampling are being revised and currently under public consultation (New Zealand Standard, 2014). Therefore, accuracy of automatic milk sampling devices used on AMS units and the milk sampling devices used by certified providers in CMS in collecting representative milk samples was assessed using ICAR (2012) standards only. The current study applied the limits set for milk recording devices with a sampler. For these types of samplers, ICAR (2012) only presents limits for fat percent. The current study applied these limits also to crude protein percent and SCC, and presented the results for all milk components with indications of the 95% and 99% confidence intervals around the limit for standard deviation. This means that 95% of the milk samples should be within 1.96 times the standard deviation limit and 99% of the milk samples should be within 2.57 times the standard deviation limit, where the standard deviation limit is 0.10% (ICAR, 2012).

Results of the composition analyzes of the reference samples (n = 6) collected manually at AMS units (Process 3, Figure 1) were averaged to serve as gold standards. The composition result of the first run for milk samples collected by the automatic milk sampling device was compared with this gold standard. Milk samples in Sample Tray I (Figure 2) collected at CMS were also analyzed in duplicate, but only results of the first run were used. Thus, the first results of the four reference samples collected manually per milk sample (Process 2, Figure 2) were averaged to serve as gold standard for CMS. The first results of the one to five milk samples that were collected from the milk sampling device used by certified providers (Process 1; Figure 2) were also averaged (if applicable) to compare with this gold standard.

Data analyses were conducted in GenStat (VSN International, 2013). Graphs were created with the package lattice 0.20-24 (http://lattice.r-forge.r-project.org/index.php) in R version 3.0.2 (www.R-project.org). Results for SCC were $\log_{10}$ transformed prior to the analyses. As the current study's focus is on accuracy of milk sampling devices (milk meters and automatic milk sampling devices) used on AMS, results of AMS are presented per milk recording test day. By doing this, potential differences between farm type, season, breeds, and region would be made visible. Results for milk sampling devices used by certified providers are merged together in the creation of plots. This was done to provide results for comparison with AMS, and not to demonstrate the accuracy of each certified provider separately.

## RESULTS

### *Accuracy of Milk Meters (AMS) and milk sampling devices (CMS) in Assessing Milk Yield*

There were 189 milk samples analyzed to assess the accuracy of milk meters used by AMS units in estimating milk yield, and 943 milk samples were analyzed to assess accuracy of milk sampling devices used by certified providers for CMS (Table 2).

Evaluating the accuracy according to ICAR (2012), milk meters used by AMS units complied for both standard deviation and bias in one out of eight milk recording test days (12.5%) for test bucket weights between 2-10kg and in two out of eight milk recording test days (25%) for test bucket weights >10kg (Table 3). In comparison, milk sampling devices used by certified providers complied for both standard deviation and bias in 11 out of 21 milking sessions (52%) with test bucket weights between 2-10kg and in eight out of 19 milking sessions (42%) with test bucket weights >10kg (Table 4). For CMS milk sampling devices, for the majority of milk recording occasions, the bias was <0.4 kg with a standard deviation of <0.5 kg for test bucket weights between 2-10 kg, and <4% and <5% for bias and standard deviation, respectively, for test bucket weights >10 kg. If these limits were applied to milk meters used by AMS units, then one more milk recording test day would comply for both bias and standard deviation (test day 12; Table 3) for both milk yield categories.

With the exception of two milk recording test days, milk meters were accurate in estimating milk yield when evaluated according to accuracy criteria of the New Zealand Standard (2007; Figure 3). When aggregating all AMS milk samples and analyzing them as one milk recording test day on 189 cows, 15 out of 189 milk samples (7.9%) fell outside the 20% difference band from the gold standard, compared with the 1% that are allowed to fall outside this limit. Excluding the two milk recording test days where the milk meters were clearly inaccurate, resulted in two out of 139 samples (1.4%) falling outside the 20% difference band. In comparison, milk sampling devices as used by certified providers were slightly more accurate in estimating milk yield (Figure 4) when evaluated according to the New Zealand Standard (2007); Ten out of 943 milk samples (1.1%) fell outside of the 20% difference band from the gold standard.

The two milk recording test days where milk meters were clearly inaccurate in estimating milk yield happened to occur on the same farm. Results from the other milk recording test days suggest that farm type (housed vs. pasture-based, high vs. low input), breeds, season, and region do not influence the accuracy of milk meters in estimating milk yield (Figure 3).

***Accuracy of Milk Sampling Devices in Collecting Representative Milk Samples***

To assess the accuracy of the automatic milk sampling devices on AMS units and milk sampling devices used by certified providers at CMS in collecting a representative milk sample for milk composition analysis, 202 milk samples were analyzed for AMS and 934 milk samples for CMS (Table 2). Not all CMS milk samples, however, had results for fat and crude protein percent and SCC, as some SCC analyses were missed or sample identification numbers did not match and, therefore, results were deemed invalid. A total of 841, 934, and 633 milk samples for fat percent, crude protein percent, and SCC, respectively, were included for further analyses. Results for SCC were reported for four milk recording occasions only.

Figure 5 demonstrates that, for fat percent, in eight out of 11 AMS milk recording test days (73%) automatic milk sampling devices were able to collect milk samples where none fell outside the limit set by ICAR (2012). However, when all milk samples were aggregated and analyzed as one milk recording test day on 202 cows, 7 out of 202 (3.5%) milk samples collected by automatic milk sampling devices fell outside the 99% ICAR limit. Findings for fat percent were similar for milk sampling devices used by certified providers in CMS: in 5 out of 12 milk recording test days (42%) milk sampling devices collected milk samples where none fell outside the limit set by ICAR (2012). Aggregating all milk samples and analyzing them as one milk recording tests day on 841 cows, however, resulted in 145 out of 841 milk samples (17.2%) that fell outside the 99% limit set by ICAR (2012; Figure 6).

Applying the same ICAR accuracy standards for fat percent to crude protein percent, automatic milk sampling devices on AMS units were able to collect milk samples in nine out of 11 milk recording test days (82%) without any falling outside the 99% limit (Figure 7). When analyzing all milk recording test days as one, 2 out of 202 milk samples (1%) collected by automatic milk sampling devices fell outside the 99% limit. For milk sampling devices used by certified providers for CMS, 11 out of 12 milk recording test days (92%) had no milk samples fall outside the 99% limit. When aggregating all milk samples and analyzing them as one milk recording test day on 934 cows, this comprised 2 out of 934 milk samples (0.2%; Figure 8).

Applying the same ICAR accuracy standards for fat percent to SCC, eight out of 11 milk recording test days (73%) conducted on AMS farms had no milk samples that fell outside the 99% limit (Figure 9). This equaled to six out of 202 milk samples (2.9%) when all samples were aggregated and analyzed as one milk recording test day on 202 cows. For milk sampling devices used by certified providers for CMS, there were 6 out of 8 milk recording test days (75%) that had no milk samples falling outside the 99% limit. When aggregating the milk samples and analyzing them as one milk recording test day on 633 cows, 13 out of 633 milk samples (2.1%) fell outside the 99% limit set by ICAR (Figure 10).

Figures 5, 7 and 9 demonstrate visually that the type of farm, breed, season, and region do not influence the accuracy of automatic milk sampling devices in collecting representative milk samples.

## DISCUSSION

This study was conducted to assess the accuracy of milk sampling devices used by AMS (milk meters and automatic milk sampling devices) for developing milk recording protocols for AMS farms. This accuracy was compared with New Zealand and ICAR standards and with the accuracy of milk sampling devices used by certified providers at CMS farms.

Before each milk recording test day started on AMS farms, AMS suppliers were asked to assure that AMS units and automatic milk sampling devices were installed and conformed to their standard operating procedures. This was done by either a representative of the AMS supplier for one AMS supplier, whereas farmers checked the standard operating procedures themselves in case of the second AMS supplier. According to these latter procedures, milk meters on the AMS units were not required to be calibrated. This lack of calibration clearly influenced results negatively for two milk recording test days that happen to be conducted on the same AMS farm. Excluding these two milk recording test days did improve accuracy from 7.9% of the samples that fell outside the 99% difference band from the gold standard to 1.4% falling outside this limit. Yet, the bias and standard deviation of the milk meters still exceeded the limits set by ICAR. Moreover, the less strict New Zealand Standards were also not met by the milk meters to estimate milk yield. Results stress the importance that milk meters on AMS units require calibration on a regular basis to ensure they work as accurately as possible. Yet, even with calibration, the milk meters do not meet the accuracy standards.

The accuracy of automatic milk sampling devices used by AMS units in collecting representative milk samples were assessed using the limit for standard deviation for fat percent as described by ICAR (2012) for all components, due to the lack of limits for crude protein percent and SCC. The reported percentages that fall outside this limit are likely to be overestimated as these percentages do not take into account potential bias. Still, even when taking bias into account, automatic milk sampling devices are likely not to meet ICAR (2012) standards for fat percent and the limit set for SCC. For crude protein percent, automatic milk sampling devices are likely to fulfil the set requirement when bias is taken into account.

Data used for the current study originated from two separate but parallel running studies. Both studies had their own objectives and, as a consequence, data collection and procedures to analyze milk samples differed slightly. These differences are acknowledged together with the fact that data were collected on just one CMS research farm which was not representative of the average CMS farm in New Zealand. Additionally, one certified provider calibrated their milk sampling devices specifically for this study, despite the request to use their devices as they normally would do in the field. Despite all this, data collected at the CMS farm are still useful to demonstrate variation in accuracy of milk sampling devices currently used by certified providers in estimating milk yield and in collecting representative milk samples for composition analyses to serve as a comparison for the AMS data.

Similar to the data collected at AMS farms, the variation in accuracy of milk sampling devices used by certified providers falls outside the limits set by ICAR (2012) and New Zealand Standards (2007). This variation was much greater for fat percent compared to the variation reported for the automatic milk sampling devices used by AMS. Variation in accuracy for milk sampling devices was comparable to that of milk meters for milk yield, and to that of automatic milk sampling devices for crude protein percent and SCC. Although neither of the milk sampling devices used on AMS units nor those used by certified providers met ICAR (2012) standards, results are encouraging as they are derived from the field where it will be much more challenging to meet standards compared to laboratory settings.

Despite the fact that the milk sampling devices did not meet ICAR (2012) nor New Zealand Standards (2007) for milk yield, and fat percent nor the set limits for SCC, data from milk sampling devices used by certified providers at CMS farms are accepted by breeding companies to calculate breeding values. Moreover, these breeding companies have been able to ensure genetic gain of New Zealand dairy cattle (Amer, 2013). One could, therefore, argue that breeding companies require at least a similar or better accuracy from the milk sampling devices used on AMS farms for the information to be of value for calculating breeding values. Results of the current study suggest that the milk sampling devices (milk meters and automatic milk sampling devices) used on AMS units are similarly or more accurate than the milk sampling devices used by certified providers for CMS. When addressing the most variable component (fat percent), 27% of the milk recording test days conducted on AMS farms had data outside the 99% limit compared with 58% for milk recording test days conducted at the CMS farm. When all data were analyzed as one milk recording test day, 3.5% of the milk samples were outside the 99% limit for AMS compared with 17.2% for CMS. It can, therefore, be concluded that milk sampling devices used to collect milk recording data on AMS farms, when calibrated regularly and when installed (including the set-up and software used), conformed to the manufacturer's instructions, have similar or improved accuracy compared to CMS milk sampling devices. These results imply that milk sampling devices used on AMS should also be permitted to be used for milk recording . The results also suggest that revision of the sub-sampling requirements in the New Zealand Standard (2012), to be more aligned with ICAR (2012) guidelines, is appropriate. Future research should study whether performances specified in the revised New Zealand Standard (2014) better reflect the performance of milk sampling devices used by certified providers on CMS farms for both milk yield and milk composition. Additionally, future research should evaluate whether the 48 h collection of milk recording data as proposed by Jago and Burke

(2013) can be reduced to make it a less expensive and a more practical protocol without losing accuracy for estimating standardized 24 h yields.

## CONCLUSION

Farm type, breed, season, and region do not appear to affect the accuracy of milk sampling devices (milk meters and automatic milk sampling devices) used on AMS units to collect milk recording data. Furthermore, milk sampling devices used on AMS require regular calibration and the set-up of these devices (including software used) has to conform to the manufacturer's instructions. Milk sampling devices used on AMS units did not comply with national nor ICAR standards with regard to milk yield and fat percent. Applying the ICAR accuracy standards for fat percent to the milk components crude protein percent and SCC, then the sampling devices used on AMS were accurate in estimating crude protein percent but not in estimating SCC. However, the milk sampling devices used on AMS were similarly or more accurate compared to the milk sampling devices currently used by certified providers at CMS farms. Therefore, since the New Zealand industry is currently accepting data from milk sampling devices used on CMS farms, it is proposed that AMS milk sampling devices also should be permitted to be used for milk recording in New Zealand.

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## REFERENCE LIST

Amer, P. 2013. Sources of genetic progress snap shot. New Zealand Animal Evaluation Limited User Group Meeting, June 2013, Hamilton, New Zealand.

Bottema, J. 1992. Automatic milking: reality. Pages 63-71 in Proceedings of the international symposium on prospects for automatic milking. A.H. Ipema, A.C. Lippus, J.H.M. Metz, and W. Rossing, ed. Pudoc Scientific Publishers, Wageningen, the Netherlands.

De Koning, C.J.A.M. 2010. Automatic milking – common practice on dairy farms. Pages 52-67 in Proceedings of the First North American Conference on Precision Dairy Management, Toronto, Canada.

ICAR (International Committee for Animal Recording). 2012. Pages 316-317 in ICAR rules, standards, and recommendations for testing, approval, and checking of milk recording devices. Section 11. Accessed August 2, 2014. http://www.icar.org.html.

Jago, J.G., K. Bright, P. Copeman, K. Davis, A.K. Jackson, I. Ohnstad, R. Wieliczko, and M.W. Woolford. 2004. Remote automatic selection of cows for milking in a pasture-based automatic milking system. Proc. N.Z. Soc. Anim. Prod. 64: 241-245.

Jago, J.G., and J.K. Burke. 2013. Estimating 24-hour milk, fat, and protein yields and somatic cell count for automatically milked cows in pastoral production systems. Proc. N.Z. Soc. Anim. Prod. 73: 29-32.

Lind, O., A.H. Ipema, C. De Koning, T.T. Mottram, H.-J. Hermann. 2000. Automatic milking: reality, challenges and opportunities. Pages 19-31 in Proc. Robotic milking, Wageningen Pers, Wageningen, the Netherlands.

Miglior, F., S. de Roos, Z. Liu, M. Mathevon, A. Rosati, L.R. Schaeffer, and P. VanRaden. 2002. Report of the ICAR Working Group on lactation calculation methods. Review and update of guidelines for milk recording. Pages 227-231 in Proceedings of the 33rd Biennial Session of ICAR.

New Zealand Standard. 2007. Dairy Herd Testing (NZS 8100:2007).

New Zealand Standard. 2014. http://shop.standards.co.nz/default.htm?action=viewDraft&mod=drafts&draftId=DZ8100%3A2014. Accessed 9th of January 2015.

Rodenburg, J. 2013. Success factors for automatic milking. Pages 21-34 in Proceedings of the Precision Dairy Conference and Expo; a Conference on Precision Dairy Technologies, Rochester, Minnesota, US.

VSN International (2013). GenStat *for Windows* 16th Edition. VSN International, Hemel Hempstead, UK. Web page: GenStat.co.uk.

**Table 1.** Characteristics of participating farms with automated milking systems (AMS)

| Farm | Herd size (n) | Farm system | AMS units (n) | Milk recording test day (n) |
|---|---|---|---|---|
| 1 | 180 | Predominantly pasture fed, organic, spring and autumn calving herds, Friesian-Jersey crossbred herd | 2 | 5 |
| 2 | 320 | Predominantly pasture fed, seasonal calving, Friesian-Jersey crossbred herd | 4 | 4 |
| 3 | 180[a] | Housed, predominantly silage/TMR fed, spring and autumn calving herds, Holstein-Friesian herd | 4 | 1 |
| 4 | 500 | Housed predominantly silage/TMR fed, spring and autumn calving herds, Jersey herd | 8 | 1 |
| 5 | 150 | Predominantly pasture fed, seasonal calving, Friesian-Jersey crossbred herd | 2 | 2 |

[a] Started with AMS during the 2012/2013 milking season and was expanding herd size to 320.

**Table 2.** Number of milk samples included to assess the accuracy of milk meters in estimating milk yield and automatic milk sampling devices in collecting a representative milk sample for the five farms with automated milking systems (AMS) and to assess the accuracy of milk sampling devices used by certified providers at farms with conventional milking systems (CMS)

| **AMS: Number of milk samples used for assessing the accuracy of** | | | **CMS: Number of milk samples used for assessing the accuracy of** | | |
|---|---|---|---|---|---|
| **Milk recording test day** | **Milk meters in estimating milk yield [a]** | **Automatic milk sampling device in collecting a representative milk sample [a]** | **Milk recording occasion** | **Milk sampling device in estimating milk yield [a]** | **Milk sampling device in collecting a representative milk sample [a]** |
| 1 | -- | 10 | 1 | 156 | 153 |
| 2 | -- | 10 | 2 | 160 | 160 |
| 3 | -- | 10 | 3 | 152 | 148 |
| 4 | 18 | 20 | 4 | 159 | 160 |
| 5 | 18 | 20 | 5 | 160 | 158 |
| 6 | -- | 10 | 6 | 156 | 155 |
| 7 | -- | 10 | | | |
| 8 | 18 | 18 | | | |
| 9 | 32 | 33 | | | |
| 10 | 21 | 21 | | | |
| 11 | 42 | 40 | | | |
| 12 | 20 | -- | | | |
| 13 | 20 | -- | | | |
| Total | 189 | 202 | | 943 | 934 |

[a] Reasons why milk samples were not analyzed for milk composition or where the number of milk samples used for analyzes is different between yield and milk composition include: milk samples having no reference milk yield, milk samples received no laboratory results for milk composition, and milk composition results received from the laboratory were deemed invalid because sample identification numbers did not match.

**Table 3.** Accuracy of milk meters on automated milking systems (AMS) in estimating milk yield when evaluated against the standard described by the International Committee of Animal Recording (ICAR, 2012). Values in bold indicate that the milk yield estimate is in agreement with the ICAR standard

| **Milk recording test day**[a] | **Test bucket Milk yield 2-10 kg** | | | **Test bucket Milk yield >10kg** | | |
|---|---|---|---|---|---|---|
| | **Samples (n)** | **Bias**[b] **<0.2kg** | **SD**[c] **<0.5kg** | **Samples (n)** | **Bias**[b] **<2%** | **SD**[c] **<5%** |
| 4 | 2 | 0.86 | **0.05** | 16 | 10.1 | **3.3** |
| 5 | 5 | 1.04 | **0.26** | 13 | 9.9 | 5.7 |
| 8 | 5 | 0.85 | 1.35 | 13 | 15.2 | 8.2 |
| 9 | 21 | 1.16 | 1.54 | 11 | 12.5 | 12.9 |
| 10 | 9 | **-0.02** | 0.56 | 12 | **-1.4** | **3.5** |
| 11 | 32 | **-0.07** | **0.39** | 10 | **-1.1** | **1.6** |
| 12 | 2 | 0.27 | **0.14** | 18 | 3.8 | **3.2** |
| 13 | 15 | 0.58 | 0.67 | 5 | 6.7 | **1.3** |

[a] Milk recording test day refers to the same milk recording test day listed in Table 2.

[b] Average of the difference in milk yield estimated by milk meters on AMS units and the milk yield from weighing the test buckets.

[c] Standard deviation of the difference in milk yield estimated by milk meters on AMS units and the milk yield from weighing the test buckets.

**Table 4.** Accuracy of milk sampling devices used by two certified providers at CMS in estimating milk yield when evaluated standards described by the International Committee of Animal Recording (ICAR, 2012). Values in bold indicate the milk yield estimate is in agreement with ICAR standards (2012)

| **Milk recording occasion**[a] | **Milking session** | **Test bucket Milk yield 2-10 kg** | | | **Test bucket Milk yield >10kg** | | |
|---|---|---|---|---|---|---|---|
| | | **Samples (n)** | **Bias**[b] **<0.2kg** | **SD**[c] **<0.5kg** | **Samples (n)** | **Bias**[b] **<2%** | **SD**[c] **<5%** |
| 1 | 1 | 11 | 0.60 | 0.96 | 28 | **1.26** | 7.11 |
| | 2 | 1 | **-0.04** | n/a | 38 | **1.80** | 5.73 |
| | 3 | 9 | **0.09** | **0.31** | 30 | 2.62 | **3.35** |
| | 4 | | | | 39 | 2.05 | **2.88** |
| 2 | 1 | 39 | **0.03** | 0.76 | 1 | **0.85** | n/a |
| | 2 | 1 | **0.18** | n/a | 39 | **1.41** | **2.03** |
| | 3 | 27 | 0.28 | 0.52 | 13 | 2.82 | **2.19** |
| | 4 | 1 | -0.45 | n/a | 39 | 2.7 | **2.87** |
| 3 | 1 | 38 | **-0.10** | **0.47** | | | |
| | 2 | 37 | **0.00** | **0.28** | 1 | **-1.82** | n/a |
| | 3 | 38 | **0.07** | **0.16** | | | |
| | 4 | 32 | **-0.01** | **0.25** | 6 | **0.05** | **2.47** |
| 4 | 1 | 34 | -0.27 | **0.37** | 5 | -4.48 | 5.92 |
| | 2 | 1 | **0.11** | n/a | 39 | **-1.31** | **2.56** |
| | 3 | 6 | **-0.05** | **0.12** | 34 | **-0.79** | **3.20** |
| | 4 | | | | 40 | **-0.44** | **2.76** |
| 5 | 1 | 40 | **-0.16** | 0.95 | | | |
| | 2 | 2 | **0.09** | **0.08** | 38 | **-0.24** | **4.29** |
| | 3 | 21 | **0.01** | **0.22** | 19 | **0.67** | **1.86** |
| | 4 | | | | 40 | **1.86** | **4.15** |
| 6 | 1 | 39 | **0.04** | **0.22** | | | |
| | 2 | 31 | 0.24 | **0.40** | 8 | 2.33 | **3.38** |
| | 3[d] | 38 | **0.12** | **0.18** | | | |
| | 4[d] | 30 | **0.19** | **0.28** | 8 | 3.08 | **2.12** |

[a] Milk recording occasion refers to the same milk recording occasion listed in Table 2.

[b] Average of the difference in milk yield estimated by milk sampling devices used by two certified providers at CMS and the milk yield from weighing the test buckets.

[c] Standard deviation of the difference in milk yield estimated by milk sampling devices used by two certified herd providers at CMS and the milk yield from weighing the test buckets.

[d] One milk sample was omitted because milk yield was <2kg.

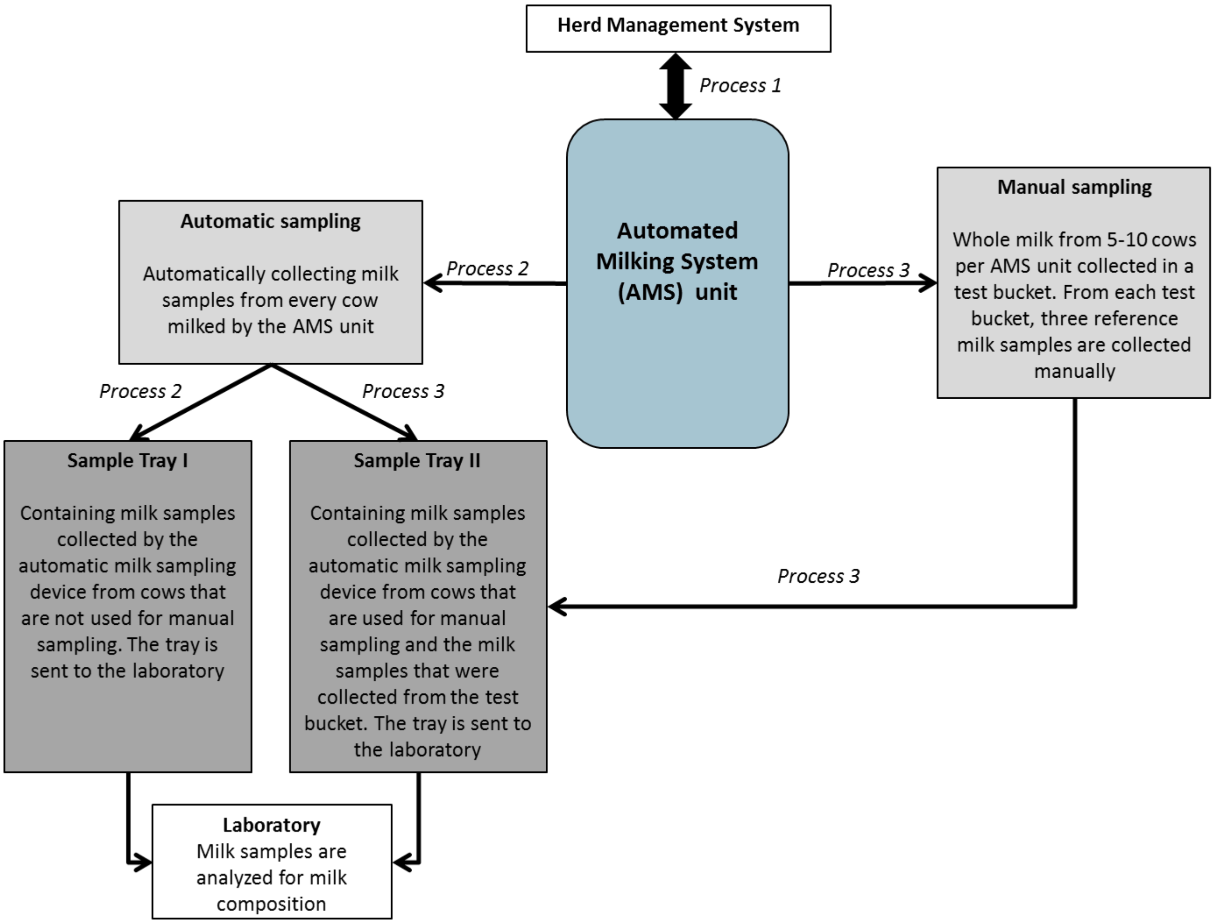


**Figure 1.** Schematic approach of collecting milk samples manually and by automatic milk sampling devices on farms with automated milking systems.

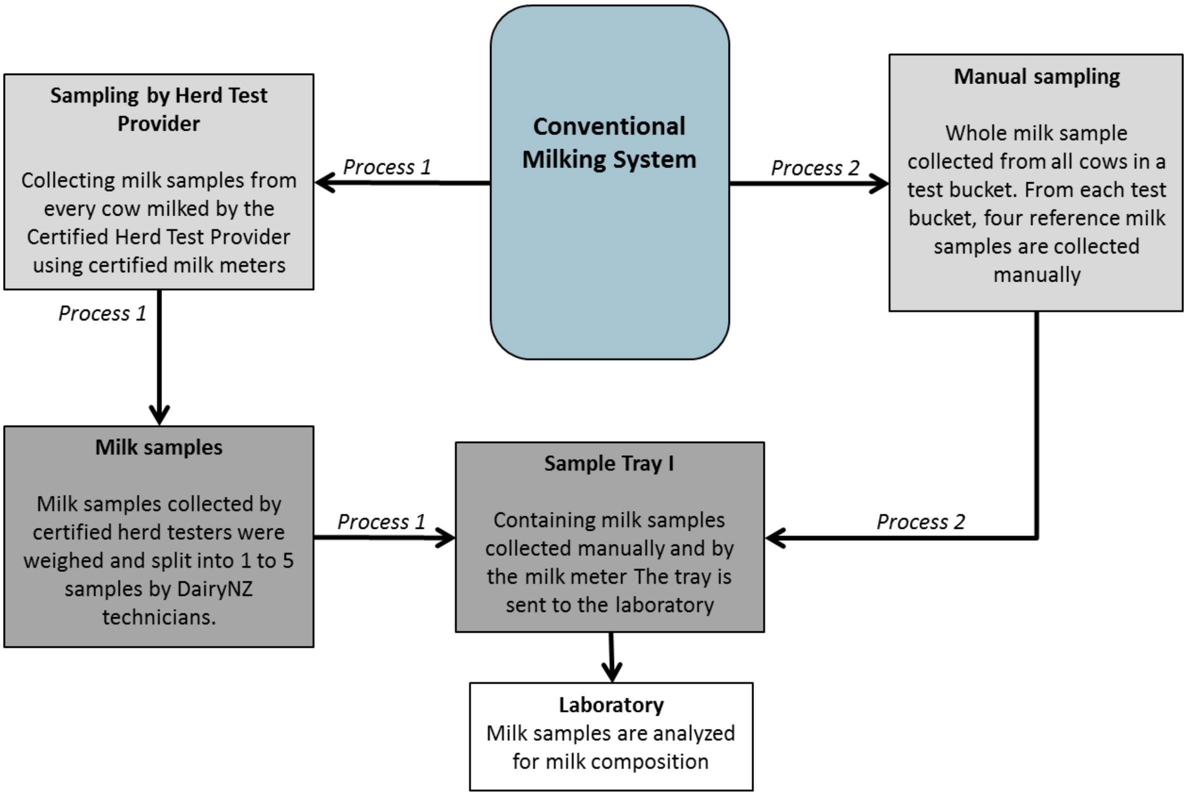


**Figure 2.** Schematic approach of collecting milk samples manually and by certified herd providers at farms with a conventional milking system.

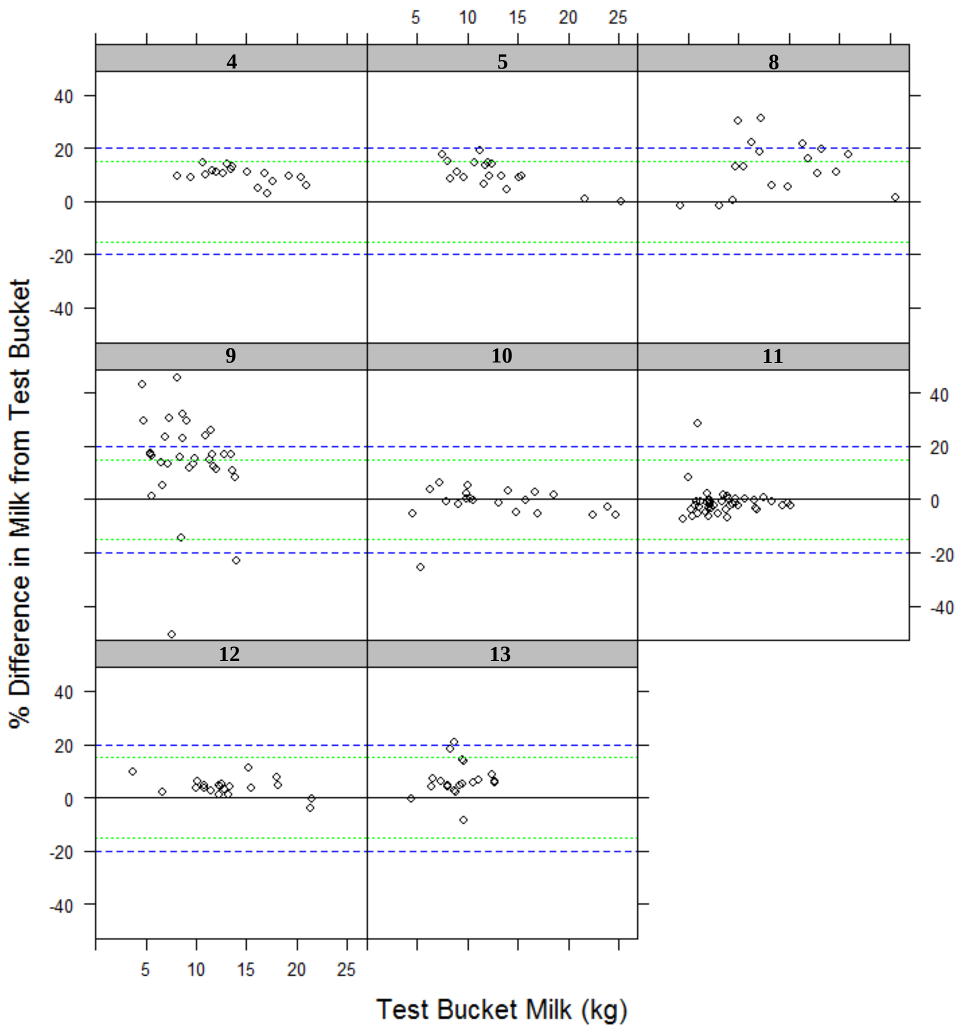


**Figure 3.** Percent difference in estimated milk yield between milk meters used by automated milking systems and the gold standard (test bucket weight). Each panel represents milk samples collected during a milk recording test day (n = 8 on five AMS farms) and panels are numbered such that they are in agreement with milk recording test days reported in Table 2. Appendix D (New Zealand Herd Test Standard 8100.2007) states that 99% of the samples should be within a 20% difference band from the gold standard (dashed lines) and that 95% of the samples should be within a 15% difference band from the gold standard (dotted lines).

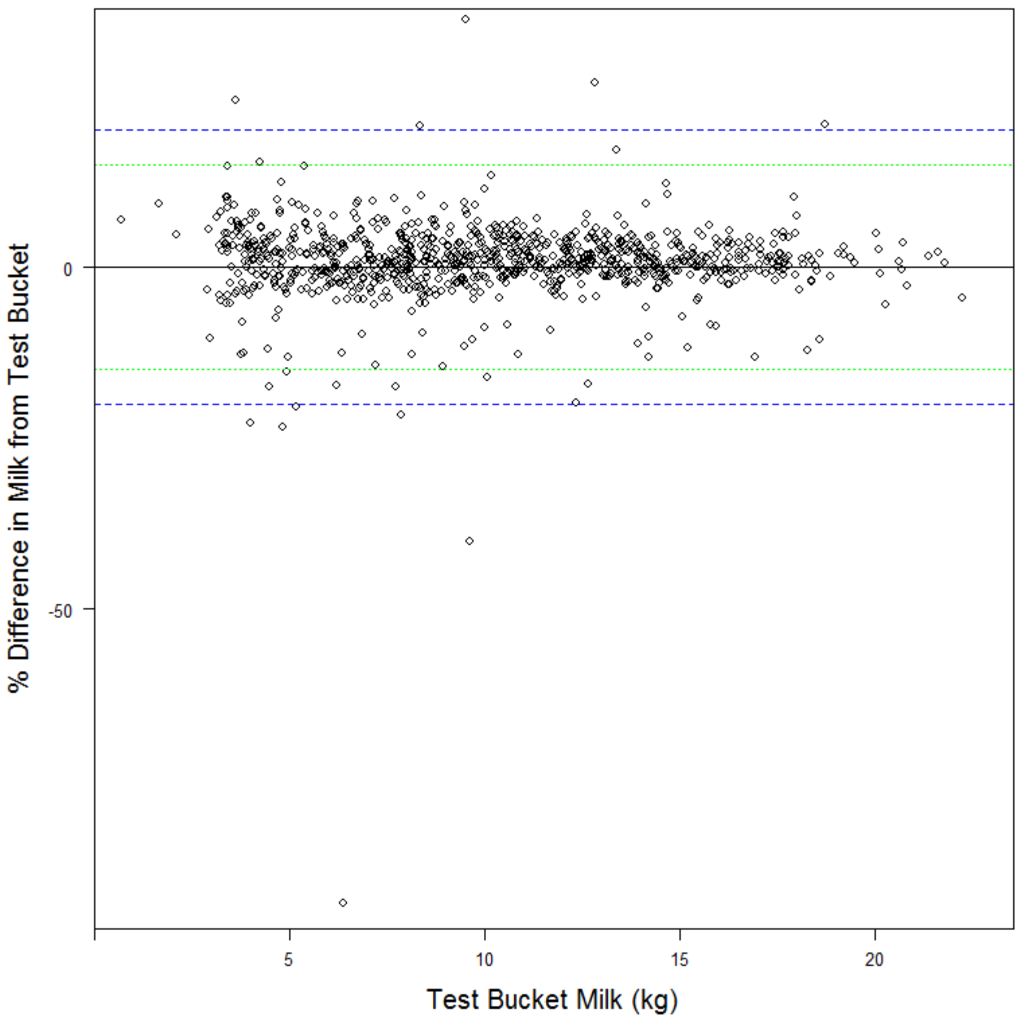


**Figure 4.** Percent difference in estimated milk yield between milk sampling devices used by certified providers and the gold standard (test bucket milk). Each black dot represents a sampled cow. Appendix D (New Zealand Herd Test Standard 8100.2007) states that 99% of the samples should be within a 20% difference band from the gold standard (dashed lines) and that 95% of the samples should be within a 15% difference band from the gold standard (dotted lines).

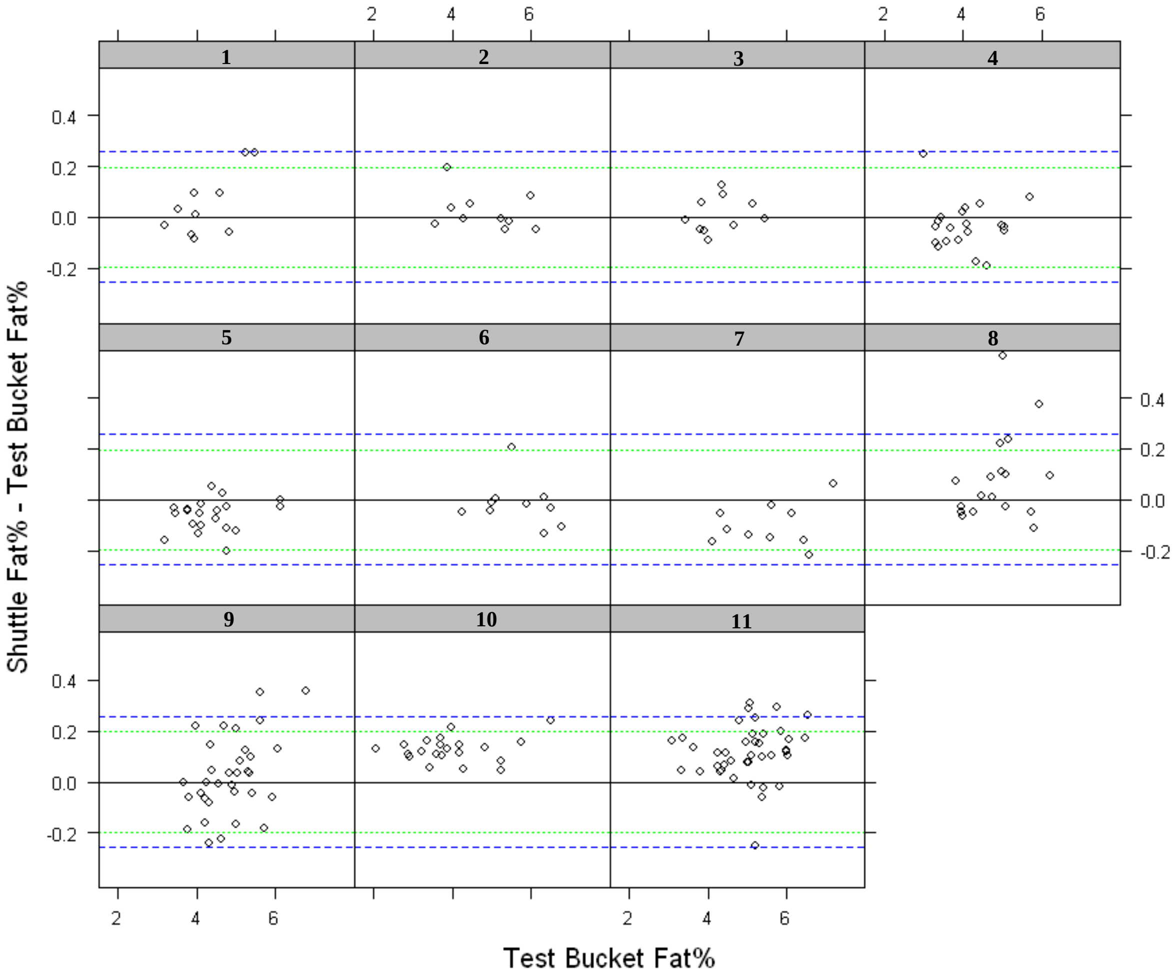


**Figure 5.** Difference in fat percent between milk samples collected by automatic milk sampling devices at automated milking systems and the gold standard (test bucket Fat%). Each panel represents milk samples collected during a milk recording test day (n = 11 from five AMS farms) and panels are numbered such that they are in agreement with milk recording test days reported in Table 2. The dotted and dashed lines represent limits reported in ICAR (2012) standards: 95% and 99% of the milk sample results should fall within these limits, respectively.

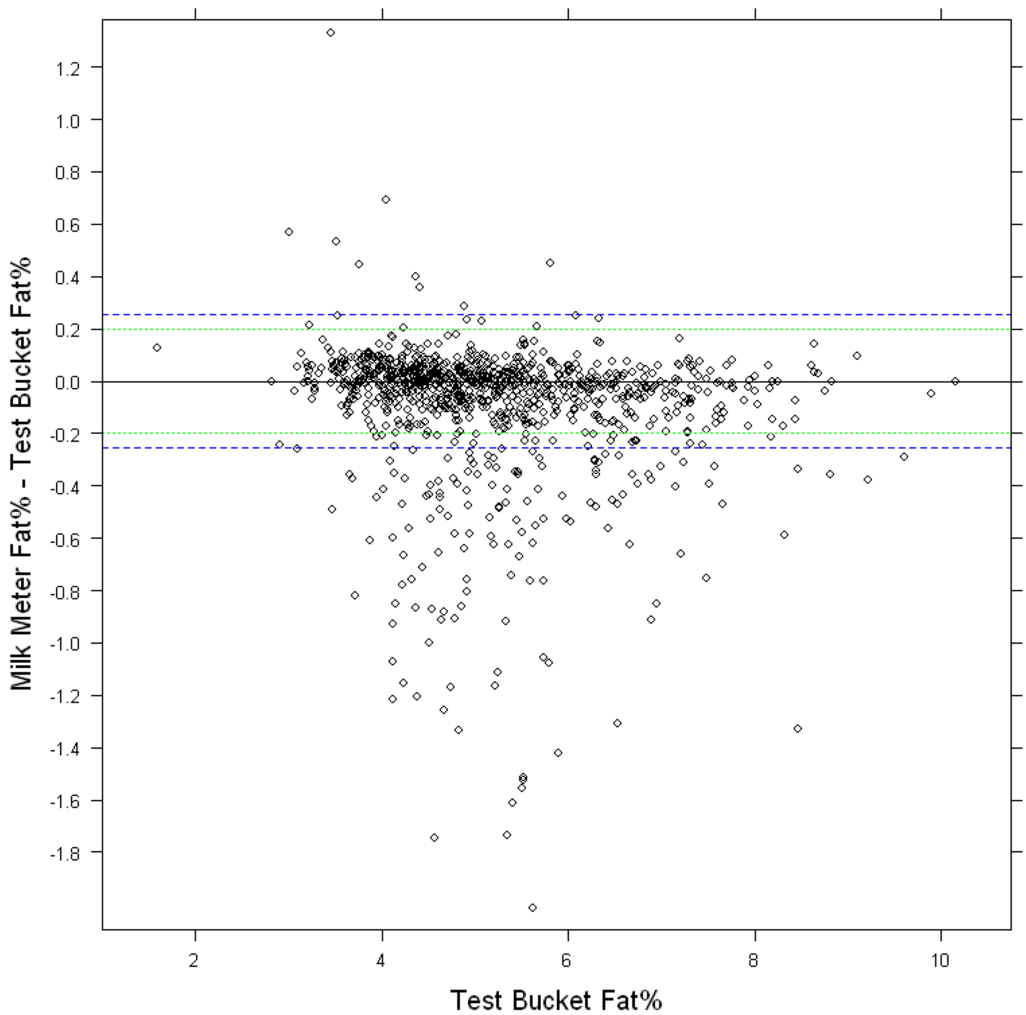


**Figure 6.** Difference in fat percent between milk samples collected by milk sampling devices used by certified providers and the gold standard (test bucket Fat%). Each black dot represents a sampled cow. The dotted and dashed lines represent limits reported in ICAR (2012) standards: 95% and 99% of the milk sample results should fall within these limits, respectively.

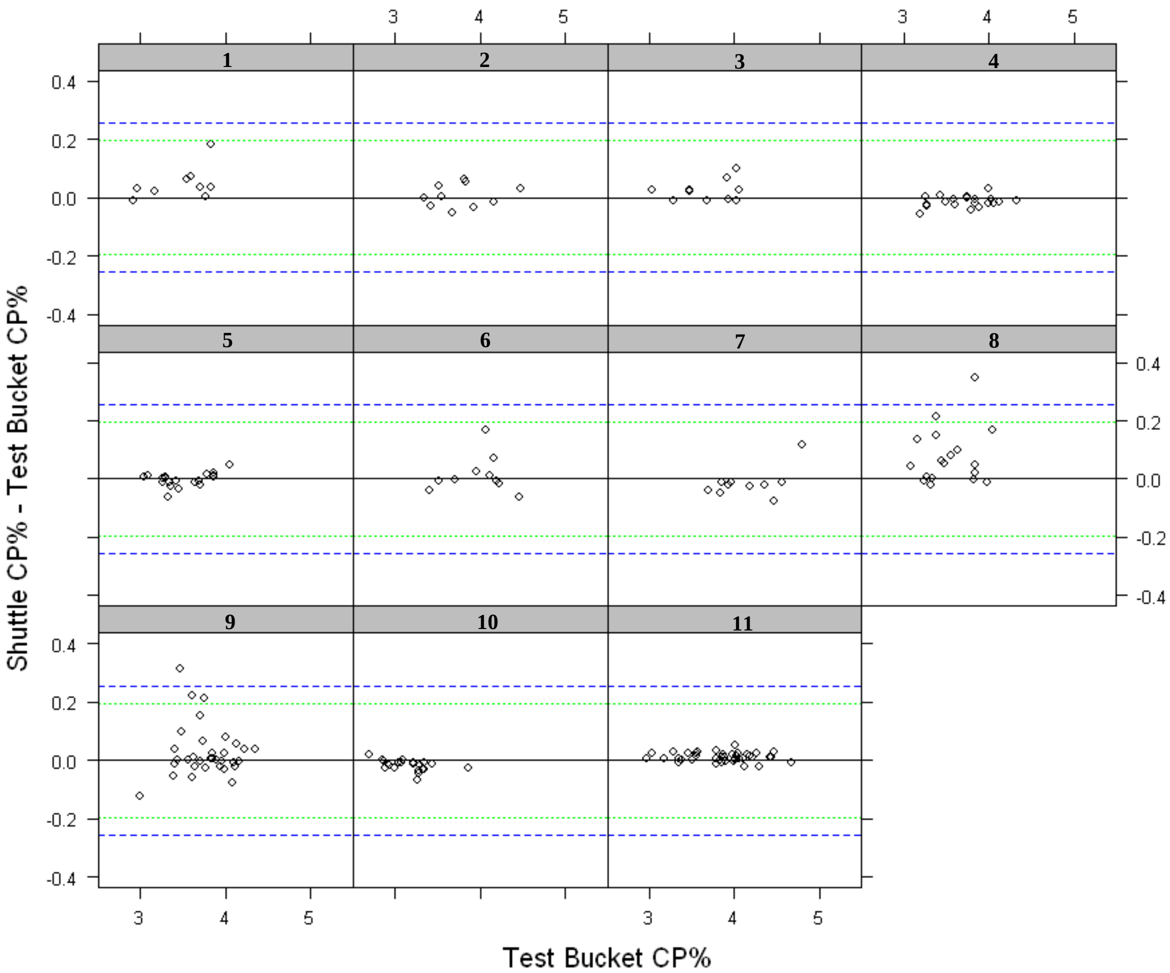


**Figure 7.** Difference in crude protein (CP) percent between milk samples collected by automatic milk sampling devices at automated milking systems and the gold standard (test bucket CP%). Each panel represents milk samples collected during a unique milk recording test day (n = 11 from five AMS farms) and panels are numbered such that they are in agreement with milk recording test days reported in Table 2. The dotted and dashed lines represent limits similar to those reported for fat percent in ICAR (2012) standards: 95% and 99% of the milk sample results should fall within these limits, respectively.

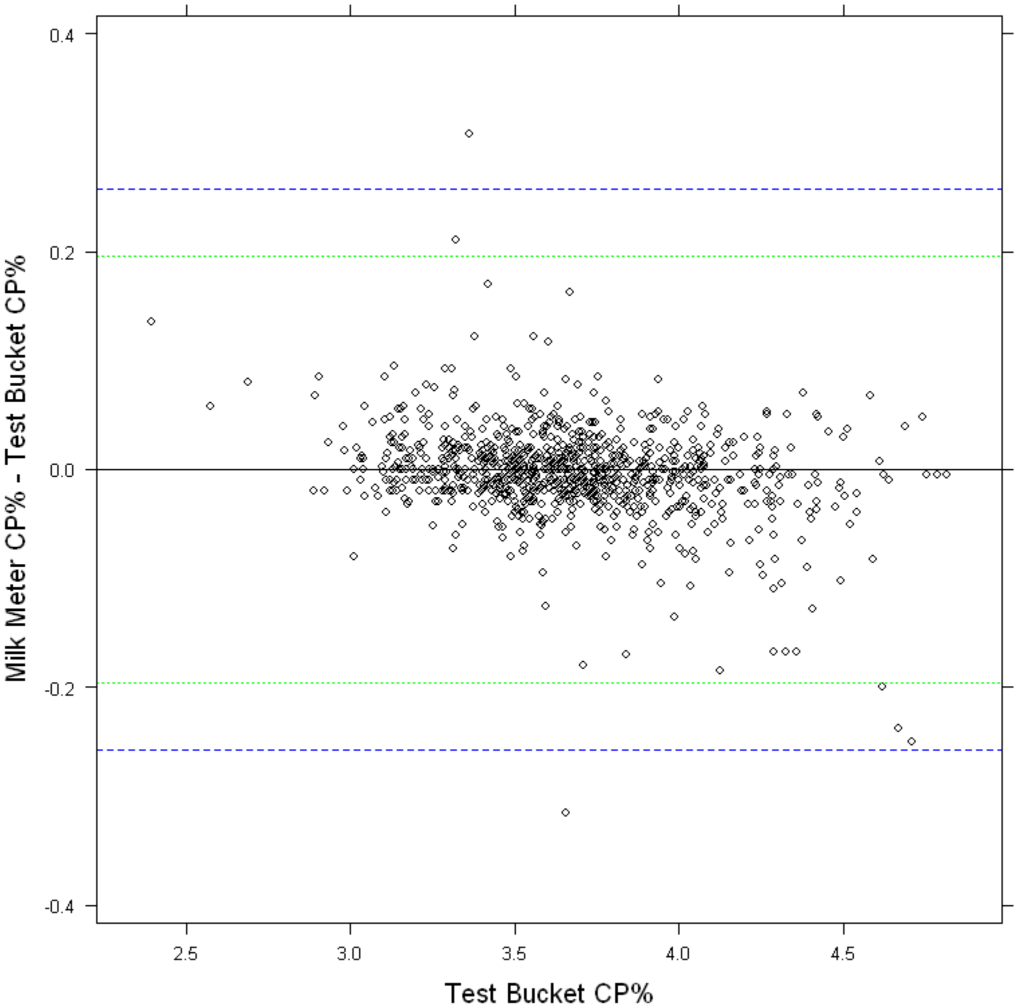


**Figure 8.** Difference in crude protein (CP) percent between milk samples collected by milk sampling devices used by certified providers and the gold standard (test bucket CP%). Each black dot represents a sampled cow. The dotted and dashed lines represent limits similar to those reported for fat percent in ICAR (2012) standards: 95% and 99% of the milk sample results should fall within these limits, respectively.

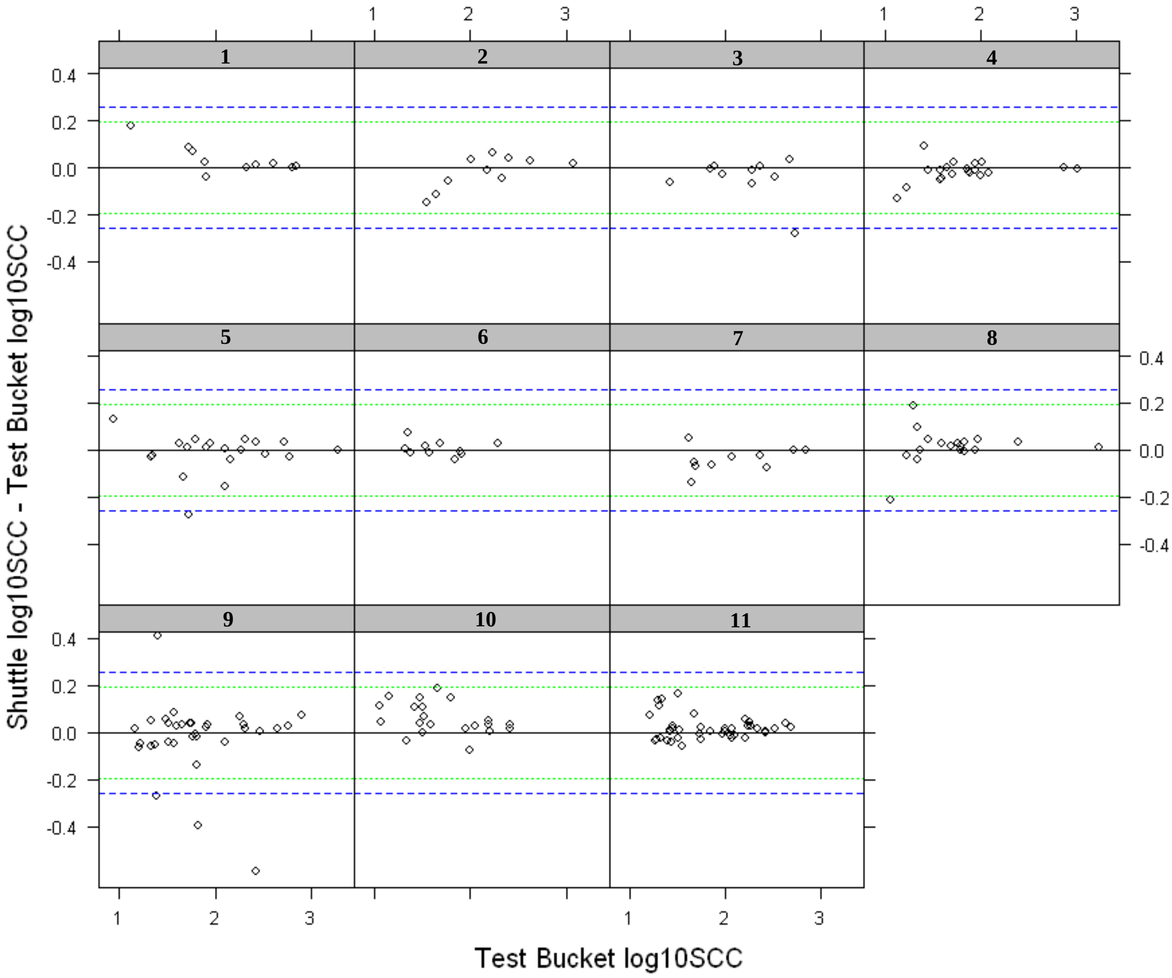


**Figure 9.** Difference in $\log_{10}$ Somatic Cell Count ($\log_{10}$SCC) between milk samples collected by automatic milk sampling devices at automated milking systems and the gold standard (test bucket $\log_{10}$SCC). Each panel represents milk samples collected during a unique milk recording test day (n = 11 from five AMS farms) and panels are numbered such that they are in agreement with milk recording test days reported in Table 2. The dotted and dashed lines represent limits similar to those reported for fat percent in ICAR (2012) standards: 95% and 99% of the milk sample results should fall within these limits, respectively.

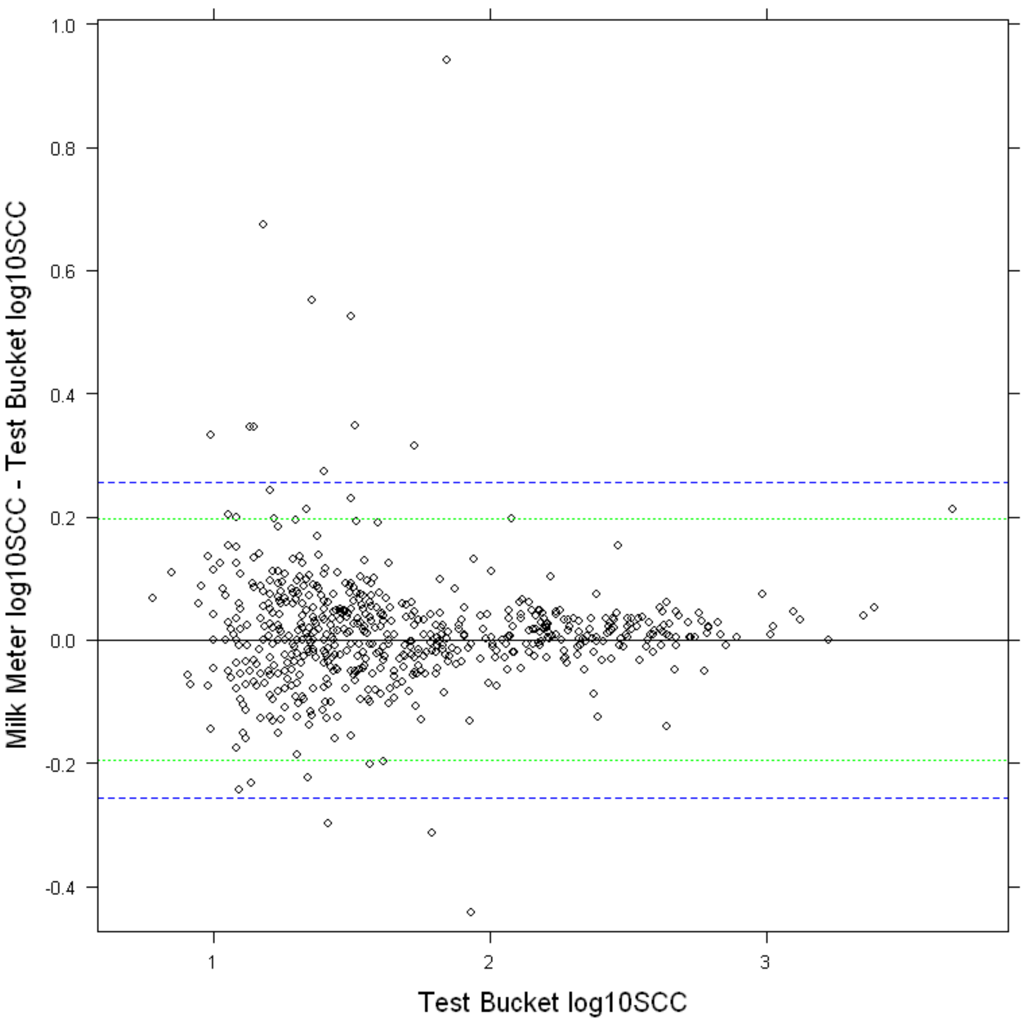


**Figure 10.** Difference in $\log_{10}$ Somatic Cell Count ($\log_{10}$SCC) between milk samples collected by milk sampling devices used by certified providers and the gold standard (test bucket $\log_{10}$SCC). Each black dot represents a sampled cow. The dotted and dashed lines represent limits similar to those reported for fat percent in ICAR (2012) standards: 95% and 99% of the milk sample results should fall within these limits, respectively.

Title:

Individual competencies for managers engaged in corporate sustainable management practices

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**Abstract**

Corporations increasingly acknowledge the importance of corporate sustainable practices. Corporate social responsibility is therefore gaining significance in the business world. Since solving corporate social responsibility issues is not a routine job, every challenge in corporate social responsibility requires its own approach; and management competencies are crucial for designing appropriate approaches towards the realization of sustainable solutions. On the basis of seven corporate social responsibility competencies synthesized from the extant literature, this research provides an empirical analysis of which of these competencies managers need in order to achieve corporate social responsibility goals within their specific context; and at which specific stage of the implementation process. The data sources are interviews with corporate social responsibility managers - whose positions and circumstances share many similarities - at four large multinational enterprises. The empirical analysis reveals that managers undertake four corporate social responsibility core tasks: I) orientation, II) reaching common ground, III) performing pilot projects, and IV) embedding results. Within the context of the analysis, the competencies: *Systems Thinking*, *Embracing Diversity and Interdisciplinarity*, *Interpersonal Competence*, *Action Competence*, and *Strategic Management* were found to be necessary. The *Embracing Diversity and Interdisciplinarity competence* was identified as the most relevant. This study contributes to the corporate social responsibility (education) literature by introducing an empirical test of which competencies are considered necessary for managers in various stages of corporate social responsibility implementation. Linking these competencies to core tasks makes them more concrete and increases the chances of interpreting them unambiguously, which in turn can aid learning trajectories in both business and education.

**Keywords**: CSR competencies, CSR managers, CSR practices, Sustainability competencies.

## 1. Introduction

Corporate Social Responsibility (CSR) is gaining significance in the business world, as corporations increasingly recognise the importance of ethical and responsible business practices to their survival and legitimacy (Dunphy et al., 2003). CSR is a business approach to sustainable development wherein companies voluntarily integrate environmental, social, and economic concerns with their business strategies - and into their interactions with stakeholders - in a quest to contribute to society in a sustainable way (Dahlsrud, 2008). This definition emphasises the voluntary nature of CSR, in that businesses engage in CSR-related activities that go beyond compliance to laws and regulations; such voluntary activities have the potential to increase the competitiveness of companies. However, since these activities can be abandoned at any time (Lozano, 2012), it is critical that they be embedded in organisations. In order to distinguish CSR from sustainability in this article, sustainability is defined as the ultimate goal of society at large (Marrewijk and Werre, 2003), whereas CSR concentrates on the contribution of companies to achieve said sustainability goal, for instance by balancing people, planet, and profit in their business practices (Wempe and Kaptein, 2002).

However, the problem is that issues like global warming, poverty, hunger and biodiversity decline cannot be solved in an easy and unilateral way. De Colle and Henriques (2013) underline this with their statement that: "despite being well-intended, CSR standards can favour the emergence of a *thoughtless, blind* and *blinkered* mindset which is counterproductive of their aim of enhancing the social responsibility of the organisation" (p. 1). Schwartz and Tilling (2009) paint a more nuanced picture. Although they acknowledge the necessity of standards (e.g. ISO 26000), they argue that CSR standards may lead to the isolation (or decontextualisation) of complex and contested social issues, while favouring their social legitimacy. Sustainability can be enhanced by (international) standards like ISO, but sustainability challenges beyond these standards have to be approached in an interdisciplinary way (e.g., people, planet and profit); by means of collaborations between different stakeholders, in which the time dimension and the context are taken into account as well (cf. Lozano, 2008). This means that sustainability remains a challenge, where every problem or challenge should be studied in its own particular context and time frame. This complexity grows even more because multiple stakeholders like businesses, governments and non-governmental organisations (NGOs) interact in sustainability issues with often conflicting value frames and ideologies (Peterson, 2009); this explains the complexity of many CSR practices as well. This complexity is also partly recognisable in other management areas like quality management or change management, but competing interests and value frames of stakeholders are particularly at stake where it comes to CSR practices.

Dealing with CSR challenges is complex, and strategic and operational decisions have to be taken at the individual level or at the level of an internal (e.g. management team, board of directors) and/or external (e.g. multiple stakeholders) team of individuals with different backgrounds, interests and value frames. Furthermore, because of the complexity of CSR challenges, standard responses will not suffice; what worked in the past does not necessarily work for the future. This explains the importance of the individual level or, as it is framed by Hesselbarth and Schaltegger (2014), the level of "the change agent". Change agents are crucial for the development of the necessary flexibility and adaptability of businesses in dealing with new and changing sustainability challenges, it is assumed that the flexibility and adaptability of change agents lie embedded in individual competencies (Rothaermel and Hess, 2007; Wals, 2010). Although it is clear that the individual level is crucial to the achievement of sustainability goals, current research in business and management literature mainly concentrates on factors affecting or enhancing sustainability performance emanating from the institutional and organisational level (see Aguinis and Glavas, 2012 for a review; Veldhuizen et al., 2013). There is a call for studies on the contribution of individuals that may affect organisational CSR-performance (Aguinis and Glavas, 2012). In educational literature (i.e. education for sustainable development), the importance of the individual level is already recognized and better researched.

In Dentoni et al. (2012), CSR competencies in the business context are summarised by making use of existing sets of CSR and sustainable development (SD) competencies provided, for instance, by De Haan (2010) and Wiek et al. (2011). In general, these sets of competencies find their origins in educational literature and are based on literature reviews; without hardly any verification whether or how these competencies are connected with managerial CSR tasks. The goal of this paper is to empirically explore the competencies identified in the extant literature as to which of them enable managers to fulfil core tasks of CSR implementation in a specific business context. Relative to the existing literature then, this research introduces and applies a method for empirically assessing CSR competencies in cases where CSR practices are implemented in other settings. To the best of the authors' knowledge, this is the first study analysing the links between CSR competencies and core tasks of CSR implementation in a business context. The first research question of this paper therefore is: 1) Which managerial CSR competencies identified in the extant literature can be connected to CSR managers' core tasks in CSR implementation? An additional research question has to be raised to answer this question, because competencies get more meaningful when related to the context in which they are performed (Mulder et al., 2005). The second research question is: 2) What core tasks of CSR implementation can be identified for CSR managers operating in a business context? Since this article concentrates on the business context, in the remainder of this article sustainability and CSR are used interchangeably to characterize the ongoing process within organizations to realise sustainable business practices.

This research is relevant from a scientific point of view because it is interesting to know which competencies really matter in CSR implementation practices, as empirical findings about what is required of the sustainability professionals are still limited (Hesselbarth and Schaltegger, 2014). Furthermore, linking competencies with core tasks makes it possible to operationalise competencies in a more concrete way, which is necessary as indicated by Adomßent et al. (2014). On the basis of several articles within the framework of Education for Sustainable Development (ESD), they concluded that it is still necessary to operationalise competencies for measurement (i.e. assessment instruments) and educational purposes (i.e. education programmes). The latter is also important from a managerial point of view. The identified competencies, accompanied by core tasks, may enhance human resource practices (e.g. selection, development, assessment) and the development of these practices in the business (education) context.

The paper is structured as follows: first a theoretical framework for CSR competencies is presented, followed by a method section in which the methods applied are elaborated upon. Finally, the findings, conclusion and discussion are presented.

## 2. Theoretical framework

In this section the theoretical underpinnings concerning competencies are presented. The first part concerns itself with competencies in general while the second part discusses competencies specifically applicable to CSR.

### 2.1 Competencies

In education, as well as in the corporate world, the term competencies is used as a vehicle for communicating about performance and learning processes of individuals (Mulder, 2001). Boyatzis (1982) and McLagan (1989) were the first to link the practice of human resource management to development in organisations. Competencies are seen as useful (e.g., Dubois and Rothwell, 2004; Lievens et al., 2004), since they can be utilized in strategic workforce planning, selection, training and development, performance management, succession planning, and motivation and rewarding. Using competencies in organisations has benefits for both organisation and employee. The former is able to align its strategic goals with the goals of the employees, and the latter experiences more transparency (Mulder, 2001). Nonetheless, the concept of competence has been applied in widely differing ways in different countries (Gonczi, 1994), in different disciplines, and at different times. It is this widespread use that is one of the major pitfalls in working with competencies (Biemans et al., 2004). In order to fully understand what is meant by competence in this study, the researchers think it is necessary to make abundantly clear how to define the concept.

One can distinguish three main conceptualisations of competence: behaviouristic, generic and holistic (Biemans et al., 2004; Sandberg, 2000). In the behaviouristic conceptualisation competencies are described as observable behaviours (no attention is paid to the individuals' input, only the output is studied) associated with the completion of each small task (Gonczi, 1994). In the generic conceptualisation of competence, which was formulated as a response to the behaviouristic approach, competencies are personal qualities (character traits included) that distinguish average performers from excellent performers (Eraut, 1994). While the context is taken into account at first, through the identification (critical incidents), it gets lost again because this approach attempts to arrive at generic descriptions. Currently, Biemans et al. (2004) indicate that most interpretations of competencies are derived from the holistic conceptualisation. Within the holistic tradition, the concept of competence is defined as follows: "Competence is the integrated performance-oriented capability of a person or an organisation to reach specific achievements. These capabilities consist of clusters of knowledge structures and also cognitive, interactive, affective and where necessary psycho-motoric skills, and attitudes and values, which are conditional for carrying out tasks, solving problems and effectively functioning in a certain profession, organisation, position and role" (Mulder, 2001, p.76). Hodkinson and Issitt (1995) distinguish two dimensions of holism. The first dimension concerns the integration of knowledge, skills and attitudes that are meaningful to someone who is (becoming) a practitioner. The second dimension of holism relates to the interrelatedness with the context; competencies can only be displayed in a context by taking core tasks or roles into account.

The aforementioned holistic conceptualisation of competence is adopted in this article, because this conceptualisation is based on the observation that competence only acquires meaning within a certain context, where professionals interact with one another. Furthermore, it acknowledges that competence is related to the notion of situated cognition: "Knowledge is situated, being in part a product of the activity, context, and culture in which it is developed and used" (Brown, Collins and Duguid, 1989, p. 32). The conceptualisations of competence in the behaviouristic and generic traditions fall short in addressing the developmental and situated nature of professional practice (Billett, 1994), and situated professionalism (Mulder, 2014). Mulder et al. (2005) have emphasised the importance of analysing meaningful combinations of core tasks before competencies can be identified or selected; said core tasks represent the situation in which the competencies are put into practice. Taking core tasks as a starting point ensures that the situation (i.e. the job and organisation) in which the competencies are to be applied is taken into account. In this approach, competence modelling consists first of a task analysis (from the perspective of the work that has to be done to ensure the connection with the situation) and second a competence analysis (from the perspective of the worker who has to do the work) (Sandberg, 2000). This corresponds with what Cheetham and Chivers (1996) have called the functional approach.

### 2.2 CSR competencies

Over the past few years, individual competencies for sustainable development have received increasing attention in sustainability literature. Significant progress has been made in conceptualising competencies for sustainable development, predominantly in the world of education (e.g., Barth et al., 2007; De Haan, 2010; Wiek et al., 2011). Steps have been taken in the corporate world as well, Willard et al. (2010) provides us with an overview of the competencies of sustainability managers. Within the educational tradition, two recent studies should be singled out for their empirical approach. In the first place, the study by Rieckmann (2012). He identified three important competencies (labelled as key competencies) for higher education: systemic thinking and handling of complexity, anticipatory thinking, and critical thinking. The significant value of this paper is the way it utilises its empirical basis (i.e. by questioning international experts in the field of SD) to achieve international agreement in the debate concerning the most important key competencies for SD. Secondly, the work of Hesselbarth and Schaltegger (2014). On the basis of MBA alumni's experiences, they empirically linked sustainability competencies with situated duties and activities. They created a so-called competency matrix for change agents in sustainability, in which they propose a structure of basic components for postgraduate education in sustainability management. To complement and advance on this strand in the literature, this research introduces and applies a method for providing empirical evidence on CSR competencies from the perspective of managers undertaking CSR implementation practices.

In this study competencies are linked to core tasks of a job, while practitioners (CSR managers) provide the empirical basis; the situatedness is taken into account. In this way, competencies might grow more meaningful (according to Mulder, 2014) and that, in turn, might lessen the differences of opinion about the proper interpretation of the competencies required for sustainability. The aim of this article therefore - as the introduction already stated - is to relate CSR (key) competencies to the core tasks of CSR managers in everyday practice, in order to get a better sense of the desired competencies with the aim of increasing meaningfulness and doing away with misinterpretations.

Dentoni et al. (2012) made use of existing frameworks for SD and CSR competencies. They used De Haan (2010) and Wiek et al. (2011) as starting points, complemented by sets of SD competencies reported by Ellis and Weekes (2008), Mogenson and Schnack (2010), Schnack (1996) and Wilson et al. (2006). From this they composed a list of seven competencies for sustainability. This list is a comprehensive overview of SD competencies up to 2011 and was taken as a starting point for this study. But neither the list by Dentoni et al. (2012), nor the lists sourced from other authors (i.e. De Haan, Wiek et al.) view competencies in relation to the tasks or job duties of sustainability managers in professional practice. This stems from the predominantly educational purposes and backgrounds of said sets of competencies.

Dentoni et al. (2012) composed a framework consisting of seven competencies required for professionals who are actively involved in dealing with sustainability in their work environment:

1. *Systems thinking competence*: the ability to identify and analyse all relevant (sub)systems across different domains (people, planet, profit) and disciplines, including their boundaries. Systems thinking competence is the ability to understand and reflect upon the interdependency of these (sub)systems, including cascading effects, inertia, feedback loops and accompanying cultures (Wiek et al., 2011).
2. *Embracing diversity and interdisciplinarity competence*: the ability to structure relationships, spot issues, and recognise the legitimacy of other viewpoints in business decision making processes; be it about environmental, social and/or economic issues. It is the ability to involve all stakeholders and to maximise the exchange of ideas and learning across different groups (inside and outside the organisation) and different disciplines (De Haan, 2010; Ellis and Weekes, 2008; Wilson et al., 2006).

3. *Foresighted thinking competence*: the ability to collectively analyse, evaluate, and craft "pictures" of the future in which the impact of local and/or short term decisions on environmental, social and economic issues is viewed on a global/cosmopolitan scale and in the long term (Wiek et al., 2011).

4. *Normative competence*: the ability to map, apply and reconcile sustainability values, principles and targets (Wiek et al., 2011).

5. *Action competence*: the ability to actively involve oneself in responsible actions for the improvement of the sustainability of social-ecological systems (De Haan, 2010; Mogensen and Schnack, 2010; Schnack, 1996).

6. *Interpersonal competence*: the ability to motivate, enable, and facilitate collaborative and participatory sustainability activities and research (Wiek et al., 2011).

7. *Strategic management competence*: the ability to collectively design projects, implement interventions, transitions, and strategies for sustainable development practices. This domain involves skills in planning (e.g., design and implement interventions), organising (arranging tasks, people and other resources), leadership (inspiring and motivating people) and control (e.g., evaluating policies, programmes and action plans) (De Haan, 2010; Wiek et al., 2011).

The following section describes the empirical analysis methods used in this research.

**3. Methods**

To answer the research questions, existing interview data from a prior research project was used. Analysing existing data for another purpose – i.e. secondary data analysis - involves pursuing a research interest which is distinct from that of the original work; be it a new research question or an alternative perspective on the original question (Hinds et al., 1997).

In this case, the stated goal of the prior research project was learning how companies engage with stakeholders – such as NGOs or governments (Selsky and Parker, 2005) - and integrate knowledge of sustainable development into the organisation (Veldhuizen et al., 2013). Within the context of this prior project, the interviews described how managers undertook CSR activities in a multi-stakeholder collaboration context; said project focused on the company involvement in cross-sector partnerships within the framework of sustainability. The analysis put forward in this article, however, focuses on the core tasks of individual professionals involved in the implementation of sustainability. The fact that stakeholder involvement is crucial for working on CSR challenges has already been pointed out in the theoretical section by referring to Peterson (2009); social responsibility implies responsiveness to the expectations of stakeholders. All in all, the reutilisation of the existing interview data for pursuing answers to other, albeit closely related, research questions was deemed legitimate. It adheres to what has been called a new perspective focus (Heaton, 2002).

Heaton (2002) summarises four methodological and ethical concerns to be taken into consideration when utilising secondary data analysis. The first issue concerns compatibility of the data. To what extent are the data amenable to the goals of the secondary analysis? In this case, all of the interviews were aimed at the analysis of organisational drivers for sustainable development. It was therefore considered to be compatible. The second issue reported by Heaton (2002) concerns the position of the secondary analyst. The requirement that was formulated to satisfy this issue is that the secondary analyst has access to the primary data. In the current study, one of the analysts involved in the secondary data analysis was also involved in collecting and analysing the primary data for the original study. The third issue concerns the transparency with which the primary data were gathered. In this study, the design, methods, and issues involved are fully reported on so as to be as transparent as possible. Finally, Heaton (2002) brings forward the ethical issue. Where sensitive data is involved, to what extent does secondary analysis violate the contract made between the subjects and the primary researchers? In this case the topic of the interviews was sustainability as well, so in that sense the contract is not deemed to have been violated.

The original research was based on case studies. Cases were selected on the basis of theoretical sampling (see Veldhuizen et al., 2013 for more details on sampling and criteria). The case study method is also appropriate for this current study because the context in which the managers operate is crucial to the tasks they perform and consequently to the competencies they need (Yin, 2003). Furthermore, the case study method lends itself to theoretical development (Yin, 2003). The nature of the study is qualitative, in the sense that in-depth interviews of four managers were used for this research. This research has an explorative nature because, to the knowledge of the researchers, it is the first time the theoretical (key) competencies are defined in relation to practical core tasks of CSR implementation.

### 3.1 Sample Selection & Data Collection

As part of the prior project from which the interviews constituting the database for this research are taken, between 2011 and early 2012 researchers questioned CSR managers of four of the fifty largest global agri-food MNE's. The agri-food business is a primary example of a sector where sustainability is important, given its role in food-related health crises (European Commission, 2001) and the enhancement of food safety (Hamann et al., 2012). Companies in the agri-food sector increasingly attempt to meet the expectations of their stakeholders (customers, governmental organisations, society at large) (Dentoni et al., 2012) in order to secure and enhance their license to operate (Blok et al., 2013; cf. Gunningham et al., 2004).

While in the prior research the four companies involved in CSPs were purposely selected (Veldhuizen et al., 2013), in this study it is the CSR managers that are analysed - rather than their companies - since this study's unit of analysis is the individual rather than the organization. The cases of the four managers are comparable based on the following three parameters: 1) all companies operate in the same industry (food manufacturers buying raw agricultural products); 2) all companies are comparable in size - being large multi-nationals procuring similar agricultural products from developing countries and emerging economies - and facing similar sustainability problems (similar in terms of global scale and complexity of the issues at hand); and 3) all CSR managers work at the decision-making European headquarters of their respective companies; all of which are based in the Netherlands.

The interviews were held with CSR managers (responsible for sustainability and CSR), were semi-structured in nature, and focused on understanding how they dealt with multiple stakeholders in the process of CSR implementation. Indirect questioning techniques were utilised to learn as much as possible from the subjects, while at the same time attempting to minimise social desirability bias (Fisher, 1993). The managers were asked to: "describe a set of CSR initiatives undertaken by themselves as their companies' CSR representatives with stakeholders over time, both within and outside CSP for SD".

### 3.2 Data analysis

Although multiple cases are used, it is not the aim of this study to compare said cases. The cases are used to describe the tasks and activities of the CSR managers in their real-life context. The data gathered in the four cases are analysed by means of a descriptive method (Yin, 2003).

The analysis of the interview data involved three steps and consisted of a combination of inductive and deductive methods. All steps were undertaken with three researchers (in each step the same researchers were involved) in order to establish intersubjectivity.

The first step consisted of the identification of core tasks. As explained above, a core task is defined as an important meaningful task in practice (Mulder et al., 2005). Core tasks undertaken in the sustainability initiatives were identified from the raw data in an inductive way. The first step was marking those excerpts from each interview that represented relevant process steps and activities in moving towards sustainability. These excerpts were subsequently labelled; the labels emerged bottom up while selecting the excerpts. Initially, each researcher examined the interview transcripts individually and, subsequently, identified excerpts and coded these excerpts with labels (open coding; Glaser and Strauss, 1967). Then the different lists of excerpts and accompanying labels were compared by the group of researchers as a whole and integrated into one list by means of axial coding (Glaser and Strauss, 1967); eventually ending up with a list of core tasks. Different rounds of coding were needed to attain sufficient intersubjective agreement (Glaser and Strauss, 1967). The result was a list of 19 core tasks to be explored and have their interrelationship examined. This resulted in four sets of core tasks arranged in chronological order: I) Orientation, II) reaching common ground, III) performing pilot projects, and IV) embedding results.

The second step was to identify labels for the competencies in order to make them, as formulated within the theoretical framework, less abstract. Based on the description of the competencies by Dentoni et al. (2012), and an existing questionnaire based on those same competencies (Lans et al., 2014), the seven competencies were provided with labels representing underlying performance criteria. This resulted in a total set of 70 labels for all CSR competencies (see appendix A). This step had a deductive character; the theory-based competence descriptions are rendered more concrete by means of these labels.

In the third and final step, the outputs of step 1 and 2 were matched. In practice this meant that the relationship between the sets of core tasks (step 1) and the competencies (step 2) were assessed. This relationship was assessed based on the overlap of both sets of concrete labels. Each researcher initially examined the relationship between the labels of the competencies and labels of the core tasks on his/her own. Subsequently, the similarities and differences were identified by the researchers as a group. Since coding relations between core tasks and competencies is mainly interpretative work (Glaser and Strauss, 1967), three rounds of discussion were needed to attain intersubjective agreement. The percentage of labels that straddled both constructs was called the overlap (see table 3). If more than 50% of the labels of the competencies and the core tasks showed overlap, there was considered to be a relationship between competence and core task. The percentage used is relatively low, owing to the explorative character of this study, but is considered appropriate at this stage.

**4. Findings**

The findings section is divided into two parts (respectively, the results of step 1 and 2) after which these two parts are integrated (step 3). The first part concerns the core activities of implementing CSR divided among four phases. In table 1, the four sets of core tasks are shown alongside the individual core tasks. These sets of core tasks are: I) Orientation, II) Reaching common ground, III) Performing pilot projects and IV) Embedding results. Each set consists of three to six core tasks and each core task is described in the table.

| Set of core tasks | Core tasks |
|---|---|
| I. Orientation | 1. Sustainability thinking<br>2. Analysing systems<br>3. Identifying consumer needs |

| | |
|---|---|
| | 4. Willingness to change<br>5. Weighing stakeholders<br>6. Strategic decision making |
| II. Reaching common ground | 7. Initiating changes<br>8. Building openness and trust<br>9. Sharing objectives<br>10. Balancing interests<br>11. Operational decision making |
| III. Performing pilot projects | 12. Collaborating<br>13. Knowledge sharing and integration<br>14. Project management<br>15. Supply chain orientation<br>16. Disseminating output |
| IV. Embedding results | 17. Creating project ownership / empowering internal change agents<br>18. Integrating approaches<br>19. Marketing |

Table 1 Sets of core tasks and separate core tasks

The second part of the results consists of the competencies and accompanying labels. In step 2, for each competence between 5 and 19 labels were identified. Appendix A shows the entire set of labels. In table 2, the accompanied core tasks are shown per competence (i.e. systems thinking competence) if the overlap between the labels representing competencies and the labels representing core tasks was 50% or more.

| Competence | Core tasks (number of core task set) | Nr. of labels per competence as theoretically constructed (step 2) | Nr. of labels of this competence affiliated with the core activities (step 3) | % overlap of the labels per competence and core task (step 3) |
|---|---|---|---|---|
| Systems thinking competence | 2. Analysing systems (I) | 12 | 12 | 100% |
| | 15. Supply chain orientation (III) | 12 | 12 | 100% |
| Foresighted thinking competence | 3. Identifying consumer needs | 10 | 2 | 20% |
| Normative competence | 1. Sustainability thinking | 9 | 1 | 11% |
| Embracing diversity and interdisciplinarity competence | 4. Willingness to change (I) | 7 | 4 | 57% |
| | 5. Weighing stakeholders (II) | 7 | 7 | 100% |
| | 10. Balancing of interests (II) | 7 | 7 | 100% |
| | 13. Knowledge sharing and integrating (III) | 7 | 5 | 71% |
| | 8. Building openness and trust (III) | 7 | 7 | 100% |
| | 18. Integrating approaches (IV) | 7 | 6 | 86% |
| Interpersonal | 9. Sharing objectives (II) | 8 | 7 | 88% |

| | | | | |
|---|---|---|---|---|
| competence | 10. Balancing of interests (II) | 8 | 6 | 75% |
| | 8. Building openness and trust (III) | 8 | 8 | 100% |
| | 17. Creating project ownership/empowering internal change agents (IV) | 8 | 4 | 50% |
| Action competence | 7. Initiating changes (II) | 5 | 5 | 100% |
| | 11. Operational decision making (II) | 5 | 4 | 80% |
| Strategic management competence | 6. Strategic decision making (I) | 19 | 9 | 51% |
| | 14. Project management (III) | 19 | 16 | 84% |

Table 2 Percentage of overlap between the labels of competencies and the labels of core activities

Table 2 shows us that the labels of five competencies show sufficient overlap with labels of core tasks. These competencies are: *Systems thinking*, *Embracing diversity and interdisciplinarity*, *Interpersonal*, *Action* and *Strategic management*. The competencies *Normative* and *Foresighted thinking* are not linked to core tasks during the analysis. Except for *Action,* all competencies are deemed necessary in more than one or even more than two sets of core tasks. In the first set of core tasks (Orientation) three competencies are identified as necessary: *Systems thinking*, *Embracing diversity and interdisciplinarity*, and *Strategic management*. In set II (Reaching common ground), there are also three competencies that are identified as necessary for performing the core tasks: *Embracing diversity and interdisciplinarity*, *Interpersonal*, and *Action*. In set III (Performing pilot projects), there are even four competencies that are considered necessary: *Systems thinking*, *Embracing diversity and interdisciplinarity, Interpersonal*, and *Strategic management*. In set IV (Embedding results), two competencies are considered necessary: *Embracing diversity and interdisciplinarity*, and *Interpersonal*. In all sets the *Embracing diversity and interdisciplinarity* competence is viewed as vital to the core tasks of implementing CSR; table 3 provides an overview. In this table the relationships between the competencies and the sets of core tasks is shown. Where competencies were related to one or more of the core tasks in the sets of core tasks, a mark was placed in the corresponding box.

| | I Orientation | II Reaching common ground | III Performing pilot projects | IV Embedding results |
|---|---|---|---|---|
| Systems thinking competence | X | | X | |
| Embracing diversity and interdisciplinarity competence | X | X | X | X |
| Interpersonal competence | | | X | X |
| Action competence | | X | | |
| Strategic management competence | X | | X | |

Table 3 Competencies underpinning sets of core tasks for realizing sustainability

Reading the content of table 3, it illustrates clearly that the this study does not identify the competencies *Normative* and *Foresighted thinking* as necessary for the realisation of CSR and that *Embracing diversity and interdisciplinarity* is the one that is needed in all sets of core tasks for the realisation of CSR.

Furthermore, table 3 shows that when applying the 50% rule, the following core tasks are excluded for a lack of overlap: *sustainability thinking* (only 11%), *identifying consumer needs* (only 20%), *collaborating* (no overlap at all), *disseminating output* (no overlap at all) and *marketing* (no overlap at all). This does not mean that those core tasks are unimportant; it just means that they do not relate to the competencies as put forward by theory. This indicates that other competencies need to be identified, because the current ones cannot be linked to these core tasks.

**5. Discussion**

Within the context of this research, the competencies *Foresighted thinking* and *Normative* were not recognised in the CSR practices of the four CSR managers. This does not mean that these competencies are totally unimportant; both Rieckmann (2012) and Hesselbarth and Schaltegger (2014) provide empirical evidence for both competencies (or comparable constructs). The results of this study only indicate that those competencies are not related to the core tasks of the four CSR managers under analysis.

In other words, within the specific context of these CSR managers, *Foresighted thinking* does not appear to be necessary anymore. This could lead to the interpretation that *Foresighted thinking* is only necessary at the point in time when the decision to start working on sustainability is taken by the board of directors, while for other people within the organisation (CSR managers in this case) it is not necessary, from an organisational point of view, to think foresightedly. This possible explanation would be consistent with what is depicted by Maon et al. (2008): each phase of CSR implementation (i.e. sensitize, unfreeze, move and refreeze) demands different activities and qualities from managers and organisations. Following this line of reasoning, *Foresighted thinking* could be relevant in the starting (sensitize) phase and lose its importance in the other phases (unfreeze, move and refreeze) where the analysed managers currently reside.

The *Normative* competence also went unrecognised in the specific setting of the analysed managerial CSR practices. Sustainability is undeniably a normative concept, as it does not describe the world as it is but as it should be. In the *Normative* competence, values, principles, goals and targets are negotiated and it includes such broad concepts as integrity, equality and justice (Wiek et al., 2011). In this respect, normative competence concerns itself with the way companies *should* operate. According to this view on normative competence, a plausible interpretation of this result is that managers do not recognise the *Normative* competence in their CSR practice because it has been internalized in their behaviour. Another, yet still plausible, interpretation is that the apparent absence of normative competence in the dataset may indicate structurally low levels of normative competence within the selected business context. This, in turn, could explain some of the conflicts between companies and NGOs with regards to value frames and trade-offs between ecological and economic interests (Peterson, 2009). In this respect, one could argue that these companies are not acting in an ethical fashion. This could, for instance, be due to a strong focus on profit maximisation. In this respect, these findings could be seen as confirmation of the classical view of the firm as non-ethical, or of the fact that these competencies are not necessary (anymore) in the phase the participating companies find themselves in.

*Action* competence is only recognised in relation to the second set of core tasks (reaching common ground). This could be seen as a surprising result because one would expect that the *action* competence might be important while performing pilot projects (III) as well. Action competence, however, means to actively involve oneself in responsible actions for the improvement of the sustainability of social-ecological systems (De Haan, 2010; Ellis and Weekes, 2008; Mogensen and Schnack, 2010). Because action competence (with labels such as: pro-activeness in decision making, taking responsibility, and perseverance of goals) concentrates on the personal involvement and personal actions of a CSR manager (De Haan, 2010) and not on the activity of other members of the company (e.g., line-managers, support staff). This may explain why action competence is in fact important for the second set of core tasks, namely to reach common ground. This implies that CSR managers initiate action and bring parties together when they deem it necessary.

*Strategic management* competence and *Systems thinking* competence are both identified as important to the set of core tasks Orientation (I) and Performing pilot projects (III). This can be explained by the fact that management in this first phase has to be performed mainly outside of the company (i.e. with stakeholders) and be seen within the larger context. The third set of core tasks concerns mainly internal (strategic) management. CSR managers' systems thinking focuses mainly on the product or process level. For example, systems - as described by Wiek et al. (2011) - are abstract by nature, whereas in the practice of the CSR manager systems equate to products. Both competencies are needed at two different levels which implies differing operationalisations of these competencies in relation to the different sets of core tasks.

Furthermore, *Interpersonal* competence is considered important in the last two sets of core tasks (performing pilot projects and embedding results). It turns out that convincing one's company's employees and managers to participate in a pilot project is of vital importance. And the execution of that core task depends heavily on the interpersonal competencies of CSR managers. After convincing the employees and management, it is important that CSR managers keep sustainability on the agenda and embed the results in daily practice. Interpersonal competencies turn out to be very important in this set of core activities as well.

Finally, the results suggest that the *Embracing diversity and interdisciplinarity* competence is the one that is identified as necessary for all sets of core tasks. It is relevant to all sets because the diversity of stakeholders and their values and opinions are important while also being subject to change. So, it is necessary to constantly review stakeholder opinions (internally and externally) and take those considerations into account. Interdisciplinarity is also present in all sets of core tasks. CSR managers have to cooperate with people representing different disciplines in each set of core tasks; with NGOs in the first (Orientation) phase, for example, and in later stages with representatives of internal company disciplines (in project teams with representatives from different departments, for example). In the research by De Haan (2010) interdisciplinarity is merely considered in terms of topics (poverty or economics) that have to be analysed and evaluated in the past and present. When operationalising this competence in the context of CSR managers, it mainly comes down to working with people with a different (disciplinary) background. CSR managers constantly work with groups of people from a wide range of disciplines and the composition of these groups varies in accordance with different sets of tasks. Rieckmann (2012) also confirms the significant importance of interdisciplinary work, empathy, and change of perspective; although not as one of the three most important key competencies. This might be explained by the different empirical bases (i.e. education and corporate) on which the conclusions were drawn.

It is shown that each verified competence has its own role to play in a particular set of tasks. The operationalisation of the same competence differs per set of core tasks, thus giving more in-depth understanding of what CSR competencies encompass. This makes the competencies more meaningful, comprehensible in practice and less exposed to ambiguous interpretations, which is beneficial for training and assessment purposes like ESD (Adomßent et al., 2014).

Follow-up research would necessarily need to uncover which competencies are necessary to underpin those core tasks that fell out of this study's analysis. This concerns the core tasks:

*sustainability thinking*, *identifying consumer needs*, *collaborating*, *disseminating output*, and *marketing*. It should be possible, by means of interviews, to learn more about these core tasks and to identify the competencies they desire. This overview of competencies underpinning core tasks for implementing sustainability is therefore not complete yet. One would expect to find a competence like communicating with stakeholders outside the own organisation (O'Riordan and Fairbrass, 2013).

What do the outcomes of this study mean for (future) CSR managers; how can they develop these competencies? For them, it is important to receive feedback from other employees and reflect on their practical experiences so as to learn together from dealing with and solving CSR challenges. In the first place, the situational/contextual aspect is very important for learning (Billett, 1994), so general approaches for teaching these competencies are less desirable. Secondly, it is extremely difficult to approach the complexity of sustainability challenges in educational settings, although research shows that higher education is making great strides towards implementing education for sustainable development (Rieckmann, 2012; Wals, 2014; Lambrechts et al., 2013). Higher education will provide students with a necessary and firm basis through the use of service learning, for example. It remains, however, necessary to implement (learning) activities in (management) practice. Learning sustainability or CSR is a continuous and collective (learning) process (cf. Blok, 2013) and those managers that are already professionals will have to develop themselves in this area. The competencies required are too complicated to develop "on the fly". Managers need discussion and feedback, to really develop and improve these competencies.

The research described in this article is an attempt to approach CSR competencies from a situated conceptualisation of competence. The next step in research would be to actually test how the competencies and core tasks relate to each other through a more quantitative approach, while the relationships that this study revealed could be tested more broadly.

The research set-up and approach chosen in this study have their limitations; the first set of limitations relates to the secondary data analysis. In the first place, although the conditions - as set by Heaton (2002) - are met, the very nature of secondary data analysis leaves it particularly susceptible to criticism and it would be most effective when combined with other approaches (Smith, 2008). In this particular case, the data were gathered with another aim, consequently there was no chance to ask further questions on the particular topic of this article and it remains unclear whether all information that the subjects had to offer about the core tasks in relation to CSR was shared. Nevertheless, one can consider this a useful exploration of introducing and applying a method for operationalising competencies and for gauging what competencies are necessary for which CSR core tasks in management practice. Secondly, the context in which the managers under analysis operate is highly specific since the four managerial cases have key common characteristics. Thirdly, uncovering managers' competencies necessary for realising CSR is considered to be quite difficult (cf. Van Kleef and Roome, 2007); because asking managers for these competencies mostly ends in every competence being deemed important. Connecting the competence with core tasks and applying an indirect analysis prevents this problem. Where it comes to the purpose of operationalising the competencies, the set-up of this research appears to be sufficient and the results of this study should be seen as setting the research agenda. It is important to test the operationalisation on a larger scale, though. In relation to this, the researchers feel the choice to work with 50% overlap was justified. The purpose of this article, as mentioned before, was to explore how competencies and core tasks relate to each other, and in the opinion of the researchers a 50% overlap is considered sufficient to demonstrate a relationship.

The second set of limitations relates to case studies. The most important shortcoming of a case study method is the seeming lack of generalisability of the outcomes (Yin, 2009). This study incorporates four cases (i.e. CSR managers) and that is a relatively small number. The extent to which the results can be generalised is to be considered limited. The results are especially valid for managers working in agri-food companies that took the decision to effect CSR (and therefore already appointed CSR managers, for example), and are in the phase of actually working on pilot projects to implement it (unfreeze stage; Maon et al. 2009). Another pitfall of the case study approach is how to ensure the consistency in the findings. To maximise robustness two measures were taken. In the first place, the interview data were collected by means of semi-structured interviews, so they were comparable to a large extent. And secondly, because multiple researchers independently coded the interview data and subsequently met and came to a consensus on the emerging codes and categories, the reliability of the findings was increased (Baxter and Jack, 2008).

Finally, the role of CSR managers was central to this study. But, as the core tasks already show, the CSR managers are not the only persons involved in the implementation of CSR. The CSR managers could be identified as the "change agents" of Hesselbarth and Schaltegger (2014), but these professionals need to involve other employees within their organisations as well (in projects, for example). They are the ones who have to bring about change and ensure that CSR is an ongoing (and collective) learning process, which should eventually involve all company employees. In further research, it remains to be seen to what extent other employees within organisations need competencies and how these competencies are distributed among different groups of employees. Maybe it would be possible to identify specific competencies for specific sets of CSR core tasks and groups of employees within organisations. This would make the operationalisation of the competencies even more concrete.

## 6. Conclusions

To contribute to the theory and practice of CSR and competencies, two research questions guided this study. The first research question of this paper was: 1) Which managerial CSR competencies identified in the extant literature can be connected to CSR managers' core tasks in CSR implementation? To answer this question, an additional research question was raised, because competencies are more meaningful in relation to the core tasks (situation) in which they are performed. 2) What core tasks of CSR implementation can be identified for CSR managers operating in a business context?

Knowing that the results of research question 2 are conditional upon the results of research question 1, the conclusion to research question 2 is presented first. In total, four sets of core tasks were identified while analysing the transcripts of the interviews with CSR managers: I) orientation (6 core tasks), II) reaching common ground (5 core tasks), III) performing pilot projects (5 core tasks) and IV) embedding results (3 core tasks). These core tasks represent the daily tasks of CSR managers of companies that have been working on CSR for some years. Related to the first research question, the results suggest that the following competencies are to be recognised in relation to the sets of core tasks: *Systems thinking*, *Embracing diversity and interdisciplinarity*, *Interpersonal competence*, *Action competence* and *Strategic management*. These competencies all have a link with one or more sets of core tasks. Linking competencies with core tasks contextualises CSR competencies in CSR management practices and provides empirical evidence of the theoretically identified competencies.

The aim of this article was to explore which competencies would relate to CSR core tasks as identified in CSR managerial practice. This contributes to the literature by refining the existing CSR competencies theory with an empirical method that identifies the core tasks for CSR implementation while finding its basis in managerial practice. Future research at the individual level could benefit from applying this method to identify sets of relevant competencies and core tasks in different and broader contexts. Furthermore, the list of competencies in relation to core tasks has practical advantages for both corporate and educational practices. Connecting the competencies to core tasks makes these competencies more meaningful and opens up possibilities of operationalising these competencies. For both the educational context (development and assessment) and the management context (especially development) this gives concrete input for learning trajectories (i.e. service learning, peer feedback).

**References**


Adomßent, M., Fischer, D., Godemann, J., Herzig, C., Otte, I., 2014. Emerging areas in research in higher education for sustainable development – management education, sustainable consumption and perspectives from Central and Eastern Europe. Journal of Cleaner Production 62, 1-7.

Aguinis, A., Glavas, H., 2012. What We Know and Don't Know About Corporate Social Responsibility: A Review and Research Agenda. Journal of Management 38 (4), 932-968.

Barth, M., Godemann, J., Rieckman, M., Stoltenberg., U., 2007. Developing key competences for sustainable development in higher education. International Journal of Sustainability in Higher Education 8, 416-430.

Baumgartner, R.J., Winter, T., 2013. The Sustainability Manager: A Tool for Education and Training on Sustainability Management. Corporate Social Responsibility and Environmental Management. DOI: 10.1002/csr.1313.

Baxter, P., Jack, S., 2008. Qualitative Case Study Methodology: Study Design and Implementation for Novice Researchers. The Quantitative Report 13 (4), 544-559.

Biemans, H. J. A., Nieuwenhuis, L., Poell, R., Mulder, M., Wesselink, R., 2004. Competence-based VET in the Netherlands: backgrounds and pitfalls. Journal of Vocational Education and Training 56 (4), 523–538.

Billett, S., 1994. Situated Learning - a workplace experience. Australian Journal of Adult and Community Education 34 (2), 112-130.

Blok, V., 2013. The Power of Speech Acts: Reflections of performative concepts of ethical oaths in economics and business. Review of Social Economy 71 (2), 187-208.

Blok, V., Sjauw-Koen-Fa, A., Omta, O., 2013. Effective Stakeholder Involvement at the Base of the Pyramid: The case of Rabobank. International Food and Agribusiness Management Review 16A, 39-44.

Boyatzis, R. E., 1982. The competent manager: a model for effective performance. Wiley, New York.

Brown, J.S., Collins, A., Duguid, S., 1989. Situated cognition and the culture of learning. Educational Researcher 18 (1), 32-42.

Cheetham, G., Chivers, G., 1996. Towards a holistic model of professional competence. Journal of European Industrial Training 20 (5), 20-30.

Dahlsrud, A., 2008. How Corporate Social Responsibility Is Defined: An Analysis of 37 Definitions. Corporate Social Responsibility and Environmental Management 15 (1), 1-13.

De Colle, S., Henriques, A., 2013. The Paradox of Corporate Social Responsibility Standards. Journal of Business Ethics. DOI 10.1007/s10551-013-1912-y.

De Haan, G., 2010. The development of ESD-related competencies in supportive institutional frameworks. International Review of Education 56, 315-328.

Dentoni, D., Blok, V., Lans, T., Wesselink, R., 2012. Developing Human Capital for Agri-Food Firms' Multi-Stakeholder Interactions. International Food and Agribusiness Management Review 15, 61-68.

Dubois, D., Rothwell, W., 2004. Competency-Based or a Traditional Approach to Training? ProQuest Education Journals 58 (4), 46-58.

Dunphy, D., Griffiths, A., Benn, S., 2003. Organisational Change for Corporate Sustainability. Routledge, London.

Ellis, G., Weekes, T., 2008. Making sustainability 'real': using group-enquiry to promote education for sustainable development. Environmental Education Research 14, 482-500.

Eraut, M., 1994. Developing professional knowledge and competence. Falmer Press, London.

European Commission (2001). Promoting a European framework for corporate social responsibility. Green paper. European Commission.

Fisher, R.J., 1993. Social Desirability Bias and the Validity of Indirect Questioning. Journal of Consumer Research 20, 303-315.

Freeman, R.E., 2010. Strategic Management: A Stakeholder Approach. Pitman, Boston.

Glaser, B., Strauss, A.L., 1967. The Discovery of Grounded Theory: Strategies for Qualitative Research. Aldine Publishing Company, Chicago.

Gonczi, A., 1994. Developing a competent workforce. National Centre for Vocational Education Research. Adelaide.

Gunningham, N., Kagan, R.A., Thornton, D. 2004. Social License and Environmental protection: Why businesses go beyond compliance. Law & Social Inquiry 29 (2) 307-341.

Hamann, R., Giamporcaro, S., Johnston, D., 2011. The role of business and cross-sector collaboration in addressing the 'wicked problem' of food insecurity. Development Southern Africa 28 (4), 579-597.

Heaton, J., 2002. Reworking qualitative data. Sage, London.

Hesselbarth, C., Schaltegger, S., 2014. Educating change agents for sustainability – learning from the first sustainability management master of business administration. Journal of Cleaner production 62, 24-36.

Hinds, P.S., Vogel, R.J., Clarke-Steffen, L., 1997. The Possibilities and Pitfalls of Doing a Secondary Analysis of a Qualitative Data Set. Quality Health Research 7 (3), 408–424.

Hodkinson, P., Issitt, M., 1995. The challenge of competence: Professionalism through vocational education and training. Cassell, London.

Lambrechts, W., Mulà, I., Ceulemans, K., Molderez, I., 2013. The integration of competences for sustainable development in higher education: an analysis of bachelor programs in management. Journal of Cleaner Production 48, 65-73.

Lans, T., Blok, V., Wesselink., R., 2014. Learning apart together: towards an integrated framework for sustainable entrepreneurship competence in higher education. Journal of Cleaner Production 62, 37-47.

Lievens, F., Sanchez, J.I., De Corte, W., 2004. Easing the inferential leap in competency modelling: the effects of task-related information and subject matter expertise. Personnel Psychology 57, 881–904.

Lozano, R., 2008. Envisioning sustainability three-dimensionally. Journal of Cleaner Production 16, 1838–1846.

Lozano, R., 2012. Towards better embedding sustainability into companies' systems: an analysis of voluntary corporate initiatives. Journal of Cleaner Production 25, 14-26.

Maon F, Lindgreen, A, Swaen, V., 2009. Designing and implementing corporate social responsibility: an integrative framework grounded in theory and practice. Journal of Business Ethics 87, 71-89.

Marrewijk, M. van & Werre, M., (2003). Multiple levels of corporate sustainability. Journal of Business Ethics 44, 107-119.

McLagan, P.A., 1989. Models for HRD Practice. The Models. American Society for Training and Development, Alexandria.

Mulder, M. (2014). Conceptions of professional competence. In: Billett, S., Harteis C., Gruber, H. (Eds). International Handbook on Research into professional and practice-based learning. Dordrecht: Springer.

Mulder, M., 2001. Competentie ontwikkeling in organisaties [Competence development in Organisations]. Elsevier Bedrijfsinformatie, Den Haag.

Mulder, M., Wesselink, R., Bruijstens, J. Chr. J., 2005. Job profile research for the purchasing profession. International Journal of Training and Development 9 (3), 185-204.

Mogensen, F., Schnack, K., 2010. The action competence approach and the 'new' discourses of education for sustainable development, competence and quality criteria. Environmental Education Research 16 (1), 59-74.

Nidumolu, R., Prahalad, C.K., Rangaswami, M.R., 2009. Why Sustainability Is Now the Key Driver of Innovation. Harvard Business Review 87 (9), 56–64.

O'Riordan, L., Fairbrass, J., 2013. Managing CSR Stakeholder Engagement: A New Conceptual Framework. Journal of Business Ethics. DOI 10.1007/s10551-013-1913-x.

Peterson, C., 2009. Transformational supply chains and the 'wicked problem' of sustainability: Aligning knowledge, innovation, entrepreneurship, and leadership. Journal of Chain and Network Science 9, 71–82.

Rieckmann, M., 2012. Future-oriented higher education: Which key competencies should be fostered through university teaching and learning. Futures 44, 127-135.

Rothaermel, F.T., Hess, A.M., 2007. Building Dynamic Capabilities: Innovation Driven by Individual-, Firm-, and Netwerk-Level effects. Organisation Science 18 (6), 898-921.

Sandberg, J., 2000. Understanding human competence at work: An interpretative approach. The Academy of Management Journal 43 (1), 9-25.

Schnack, K., 1996. Internationalisation, democracy and environmental education. In: Breiting, S., Nielsen, K. (Eds.) Environmental education research in the Nordic countries: proceedings from the research centre for environmental and health education. The Royal Danish School for Educational Studies, Copenhagen, pp 7-19.

Schwartz, B., Tilling, K., 2009. 'ISO-lating' Corporate Social Responsibility in the Organizational Context: A Dissenting Interpretation of ISO26000. Corporate Social Responsibility and Environmental Management 16, 289-299.

Selsky, J. W., Parker, B., 2005. Cross-Sector Partnerships to Address Social Issues: Challenges to Theory and Practice. Journal of Management 31, 849-873.

Smith, E., 2008. Pitfalls and Promises: The Use of Secondary Data Analysis in Educational Research. British Journal of Educational Studies 56 (3), 323-339.

Van Kleef, J.A.G., Room, N.J., 2007. Developing capabilities and competence for sustainable business management as innovation: a research agenda. Journal of Cleaner Production 15, 38-41.

Veldhuizen, M.T., Blok, V., Dentoni, D., 2013. Organisational Drivers of Capabilities for Multi-Stakeholder Dialogue and Knowledge Integration. Journal of Chain and Network Science (forthcoming).

Wals, A.E.J., 2010. Mirroring, Gestaltswitching and transformative social learning: stepping stones for developing sustainable competence. International Journal of Sustainability in Higher Education Policy 15, 121-131.

Wals, A.E.J., 2014. Sustainability in higher education in the context of the UN DESD: a review of learning and institutionalization processes. Journal of Cleaner Production 62, 8-15.

Wesselink, R., 2010. Comprehensive Competence-based education. Unpublished dissertation, Wageningen University.

Wiek, A., Withycombe, L., Redman, C.L., 2011. Key competencies in sustainability: a reference framework for academic program development. Sustainability Science 6, 203-218.

Willard, M., Wiedmeyer, C., Warren Flint, R., Weedon, J.S., Woodward, R., Feldman, I., Edwards, M., 2010. The sustainability professional: 2010 competency survey report. Environmental Quality Management. 49-83.

Wilson, A., Lenssen, G., Hind, P., 2006. Leadership Qualities and Management Competencies for Corporate Responsibility. Ashridge, United Kingdom.

Yin, R.K., 2009. Case study research: Design and methods, Volume 5. Sage, California.

Appendix A Competencies and accompanying labels

| Competence | Labels |
| --- | --- |
| Systems thinking<br>(12 labels) | 1. Analysing sub systems<br>2. Analysing systems<br>3. Cascading effects<br>4. Causing effect relations<br>5. Reflecting on elements of interdependency<br>6. Identifying sub-systems<br>7. Identifying scale<br>8. Understanding aspects of interdependency<br>9. Identifying systems<br>10. Feedback loops<br>11. Understanding scale effects<br>12. Overview of motives |
| Foresighted thinking<br>(10 labels) | 1. Crafting pictures of the future<br>2. Assessing effects on intergenerational equity<br>3. Balancing local\global<br>4. Opportunities recognition<br>5. Balancing long-term\short-term<br>6. Innovation<br>7. Collectively evaluating pictures of the future<br>8. Assessing unintended harmful consequences<br>9. Collectively analysing pictures of the future<br>10. Creativity |
| Normative competence<br>(9 labels) | 1. Ethics<br>2. Equity<br>3. Inter and intra generational equity<br>4. Principles<br>5. Accountable for decision-making<br>6. Values<br>7. Sustainability values<br>8. Justice<br>9. Socio-ecological integrity |
| Embracing diversity and Interdisciplinary<br>(7 labels) | 1. Structure relations<br>2. Facilitating dialogue<br>3. Stimulating exchange of ideas<br>4. Proactivity in information exchange<br>5. Openness to other viewpoints<br>6. Recognition of legitimacy of different viewpoints<br>7. Involving stakeholders |
| Interpersonal competence<br>(8 labels) | 1. Enabling collaboration<br>2. Communicating<br>3. Facilitating collaboration<br>4. Empathy |

| | |
|---|---|
| | 5. Ability to motivate collaboration<br>6. Collaborating<br>7. Compassion<br>8. Negotiating |
| Action competence<br>(5 labels) | 1. Proactive in decision making<br>2. Taking responsibility<br>3. Perseverance of goals<br>4. Decision initiative<br>5. Active involvement |
| Strategic management<br>(19 labels) | 1. Evaluation of policies<br>2. Controlling<br>3. Collectively design interventions<br>4. Leading<br>5. Planning skills<br>6. Taking action<br>7. Inspiring<br>8. Organize<br>9. Implementing strategies<br>10. Measuring performance<br>11. Collectively implementing interventions<br>12. Evaluation<br>13. Arranging tasks<br>14. Motivating<br>15. Arranging resources<br>16. Arranging people<br>17. Designing transitions<br>18. Evaluation of programs<br>19. Evaluation of action plans |