Agricultural Sciences, 2023, 14, 1420-1435
https://www.scirp.org/journal/as
ISSN Online: 2156-8561
ISSN Print: 2156-8553

Evaluating Fecal Sieving Tool as an Indicator of Feed Valorization and the Impact of Feeding Strategy on Dairy Cow Performance under Farm Conditions

Nizar Salah[1*], Héloïse Legendre[1], Laurine Faivre[1], Maxime Briche[1], Raphael Gourdon[1], Valentin Nenov[2]

[1]Phileo by Lesaffre, Marcq-en-Baroeul, France
[2]Huvepharma, Flemish Region, Antwerp, Belgium
Email: *n.salah@phileo.lesaffre.com

How to cite this paper: Salah, N., Legendre, H., Faivre, L., Briche, M., Gourdon, R. and Nenov, V. (2023) Evaluating Fecal Sieving Tool as an Indicator of Feed Valorization and the Impact of Feeding Strategy on Dairy Cow Performance under Farm Conditions. *Agricultural Sciences*, **14**, 1420-1435.
https://doi.org/10.4236/as.2023.1410093

Received: September 23, 2023
Accepted: October 24, 2023
Published: October 27, 2023

Abstract

The objective of this study was to evaluate the use of a faeces sieving tool "Digescan" as an indicator of feed valorization, and to test the influence of feeding strategy on fecal particle size (PS) distribution and weight, milk performance and the possible association between them. Data from 95 trials were used. During each trial, two periods were identified: before and during live yeast probiotic (LYP) supplementation. The LYP used at 5 g/d/cow was Saccharomyces cerevisiae (CNCM I-4407, 1010 CFU/g, Actisaf® Sc47; Phileo by Lesaffre, France). Milk yield and composition were recorded. Fecal samples were taken at the end of each period and sieved with a set of two wire-mesh screens with pore sizes of 5 mm and 2 mm under running tap water. Yeast probiotic supplementation significantly reduced (P < 0.001) the quantity of particles remaining on the 5 mm (P < 0.001) and 2 mm sieve (P < 0.05). Live yeast supplementation increased significantly milk yield, energy-corrected milk, and fat corrected milk (P < 0.01). Each 10 points increase in % of PS > 5 mm was accompanied by 1.2 and 0.65 kg/d decrease in MY, 2.5 and 2 kg/d decrease in ECM and 3.2 and 2.6 kg/d in FCM before and during LYP supplementation, respectively. Fecal particle distribution appears to be a practicable tool to predict influences of feeding systems on feed valorization and performance in dairy cows. Live yeast increases dairy performance and decreases the quantity of fecal particles remaining in the two sieves after rinsing.

Keywords

Feces Sieving, Yeast Probiotic, Dairy Cow, Milk, Particle Size

1. Introduction

Because feed is the largest single expense associated with the production of milk, farmers and stakeholders in the dairy industry are focusing increasingly on optimizing feed efficiency, feed valorization and milk production because they directly affect profitability [1] and environmental sustainability [2]. In the dairy cow, these two parameters depend on rumen health and its environment which allows the cow to obtain the greatest nutritional benefit from the feed for maintenance and production [3] [4]. Feeding live yeast to ruminants has been empirically known to improve productivity, health, and well-being by optimizing the environment and the fermentation conditions of the rumen [5] [6].

For long time, *in vivo*, *in vitro* digestibility, undigestible neutral detergent fiber (μNDF) or ash insoluble ash (AIA) have been used as methods to evaluate rumen function, feed nutritive value, feed valorization and animal performance [7] [8]. Yet, these methods which necessitate specific material such as digestibility cage, cannulated animals, laboratory conditions are laborious, invasive, and expensive and could not be routinely performed on farm [9] [10] [11] [12]. To have easily measurable indicators of digestion and ration valorization in field conditions, several sieving methods of manure and faeces were used such as wet sieving [13] [14] or dry sieving [15] [16]. [17] described on-farm fecal sieving using a screen or kitchen strainer with 1.66-mm openings and a steady stream of water as an easy procedure to evaluate manure. Furthermore, a commercially available system, the Nasco Digestion Analyzer (NDA; Nasco, Fort Atkinson, WI), employs principles of wet sieving and uses 3 stainless steel screens to evaluate fecal particle size. Yet, there is no standard procedure and there is a lack of knowledge regarding the appropriate fecal evaluation method that could provide better assessment of feed valorization and ruminal fermentation. Hence, the aim of the current study was to evaluate the usefulness of a new sieving tool to investigate under on-farm conditions the evaluation of fecal PS distribution as an indication for feed valorization and to investigate the effect of live yeast probiotic (LYP) supplementation on PS distribution of faeces and performance parameters.

2. Materials and Methods

2.1. Farms and Animals

Data were obtained from 95 trials conducted in 52 different commercial dairy farms in Europe from 2012 to 2021. All farms used Holstein cows. In each trial, 10 dairy cows were used to collect faeces before LYP distribution (control group) and 10 cows with the same characteristics (same DIM, parity, MY) were observed during LYP supplementation (experimental group) for one month on average (**Figure 1**).

During all these trials, PS > 5 mm was measured. However, PS between 2 and 5 mm (2 mm < PS < 5 mm) was measured only in 68 trials. Among the 95 trials, MY was measured in 27 trials, ECM in 25 trials and FCM in 26 trials (**Figure 2**).

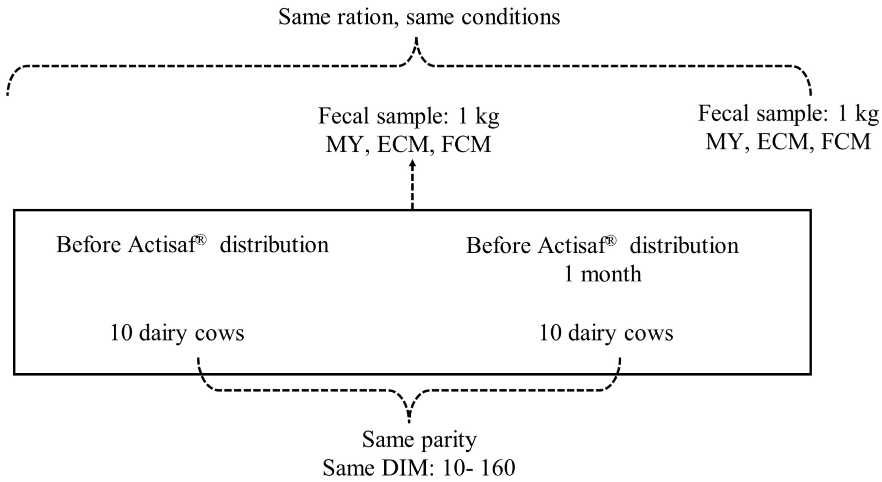

Figure 1. Schematic diagram of the experimental design.

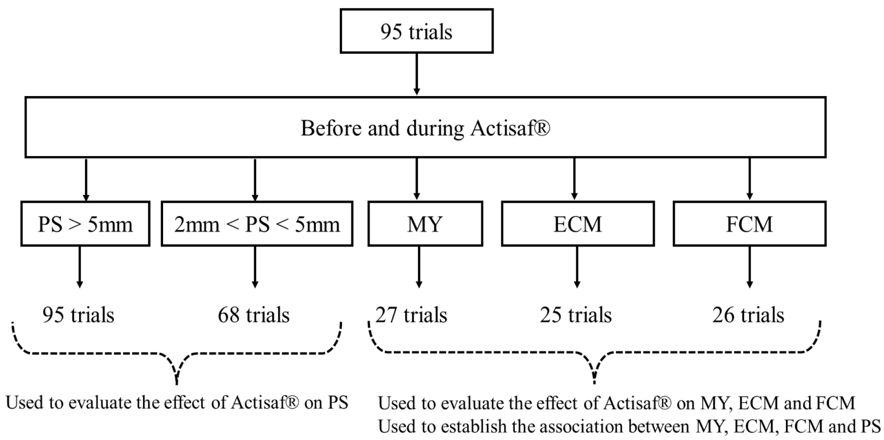

Figure 2. Number of trials used to analyze the different parameters. PS = particle size, MY = Milk yield, ECM = Energy corrected milk, FCM = Fat corrected milk.

During all the trials, the cows were fed with corn silage as basic ration and the same protocol was used. Yeast probiotic used is produced and marketed by Phileo by Lesaffre "Actisaf® Sc 47" (Saccharomyces cerevisiae CNCM I-4407).

In total, 950 dairy cows between 40 and 160 days in milk were included in the study. Milk yield, fat and protein introduced in the data base are the average obtained on 10 cows before and during the distribution of LYP. Particle size data introduced in the database was also the average obtained on 10 cows before and during LYP distribution. Two sieves of 5 mm and 2 mm (length: 30 cm, width: 20 cm and depth: 14.5 cm) were used and overlaid "Digescan tool". The 5 mm sieve was placed above the 2 mm sieve. The choice of this sieve was made following comparisons with others in terms of results, simplicity and time savings highly demanded by farmers. The dung (1 kg) was placed on the top of 5 mm sieve and then rinsed with low pressure. Rinsing was performed in 20 seconds shower intervals using circular movements to cover all the sieve set and repeated in as many 20 seconds intervals until water easily passed through the top sieve and became clean. The rinsing was carried out just on the 5 mm sieve, but between each rinsing cycle of 20 seconds, the retained particles in the bottom sieve (2 mm) were stirred with circular movements.

After each rinse, a visual inspection was done to verify the absence of small particles. Once the rinsing was finished, the residual quantity of dung remaining in each sieve was pressed during 30 second against the sieve wall and then in hands to evacuate the water according to a well detailed protocol. The residue from each sieve was then weighed to quantify the weight of PS above 5 mm and between 2 and 5 mm before and during LYP distribution (**Figure 3**). For each trial, the same person made the same measurements at the same place in the farm before and after LYP distribution to reduce bias linked to manipulation. The effect of LYP on PS and milk performances including milk yield (MY), energy-corrected milk (ECM) and fat corrected milk (FCM) was tested. The association between % PS retained in 5 mm sieve and milk parameters was also established. Energy corrected milk was estimated from the measured milk yield, fat, and protein content according to the following equation: ECM = (0.327 × kg of milk) + (12.95 × kg of fat) + (7.2 × kg of protein) [18]. Fat corrected milk was estimated through the formula of 4% FCM = 0.4 × milk yield (kg) + 15 × fat yield (kg) as stated by [19]. Milk fat and protein data were obtained from official milk recording.

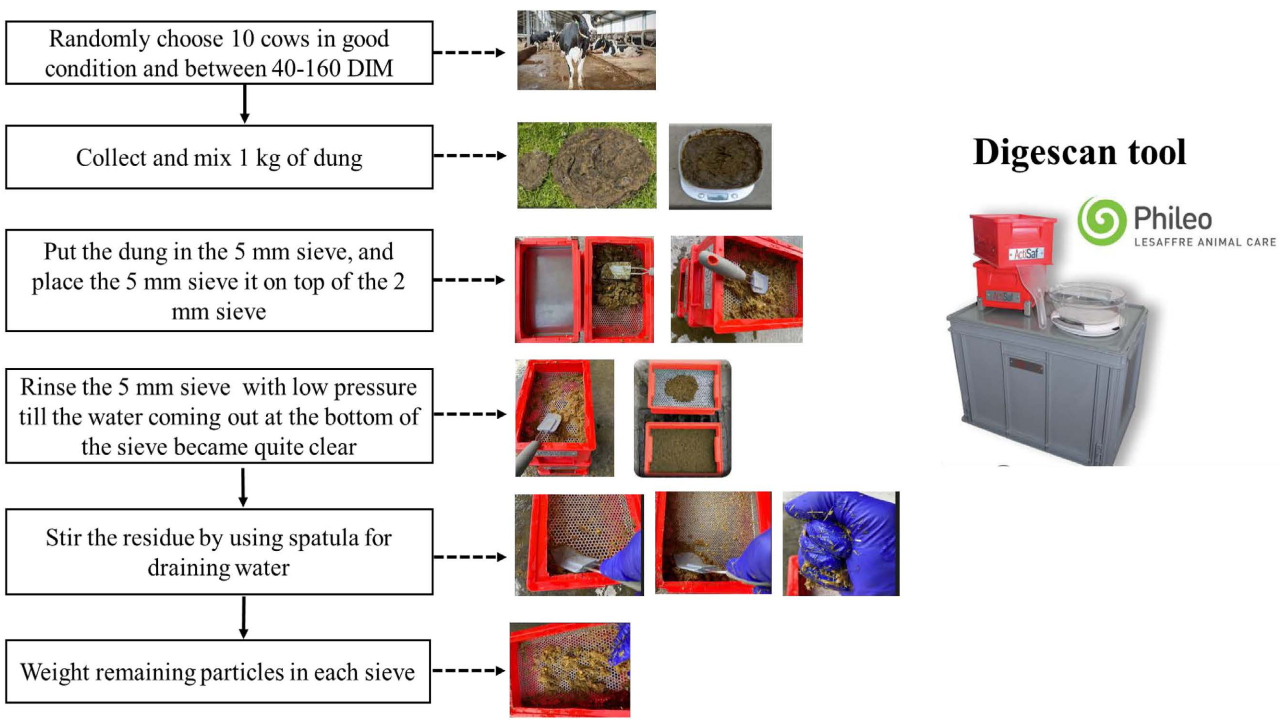

Figure 3. The different steps of sieving.

2.2. Statistical Analysis

Trials were individually encoded to be used in the model. Two complementary analyses were performed. The effect of LYP on PS was performed following the recommendation of [20] using Minitab software. The statistical model applied to the data was:

$$Y_{ij} = \mu + Treatment_i + Trial_j + E_{ij},$$

where Y_{ij} = animal response as explained variable, μ = overall mean, $Treatment_i$ = fixed effect of the treatment (before and during LYP), $Trial_j$ = random effect of the trial j, E_{ij} = random residual error.

The association between % PS retained in 5 mm sieve and milk parameters was performed by using linear regression before and during the distribution of LYP to validate the Digescan™ tool efficiency. For each variable, a graphic verification of data quality was done via boxplot to identify outliers. Outliers were considered for data appearing with an asterisk in the boxplot (and thus for values with ± 1.5 interquartile range) and outside the 95% confidence interval of the normality probability plot. This method was accompanied by a verification of normalized residuals (*i.e.*, differences between model-predicted and measured value of the studied parameter, divided by the standard deviation of the residuals' values). For each dependent variable, experiments presenting normalized residuals greater than 2.0 or less than 2 were discarded from the analysis but not from the analyses of other variables. The effect was considered significant at $P < 0.05$, considered a tendency toward significance at $P < 0.1$, and non-significant at $P > 0.1$.

3. Results

3.1. Effect of Yeast Probiotic Supplementation on Weight of Particle Size

Total weight of retained fecal particles in the two sieves after rinsing was significantly different between the two groups (290 and 226 g for control and LYP, respectively). Reported to percentage, these values correspond to 29% and 22.6% for control and LYP, respectively. The use of LYP reduced by 36% the weight and the percentage of PS retained in the 5 mm sieve ($P < 0.001$) and by 9.5% the weight of PS retained in 2 mm sieve ($P = 0.058$; **Figure 4**).

3.2. Effect of Yeast Probiotic Supplementation of Milk Parameters

Milk yield (MY) was recorded in 27 trials. Overall, 70% of those trials (19/27) showed clear positive effect of LYP on MY. There was 7% of the trials (2/27) that showed a slight reduction, 7% (2/27) that showed clear reduction in MY with LYP and 15% (4/27) showed no variation in MY (**Figure 5**). The statistical analysis showed significant positive effect of LYP supplementation on MY (28.88 and 30.20 kg/d for control and LYP group, respectively, $P < 0.01$; **Figure 6**).

Energy-corrected milk was recorded in 25 trials. Live yeast supplementation increased ECM in 18 trials, reduced slightly ECM in 3 trials and didn't have any effect in 4 trials (**Figure 5**). The statistical analysis showed significant positive

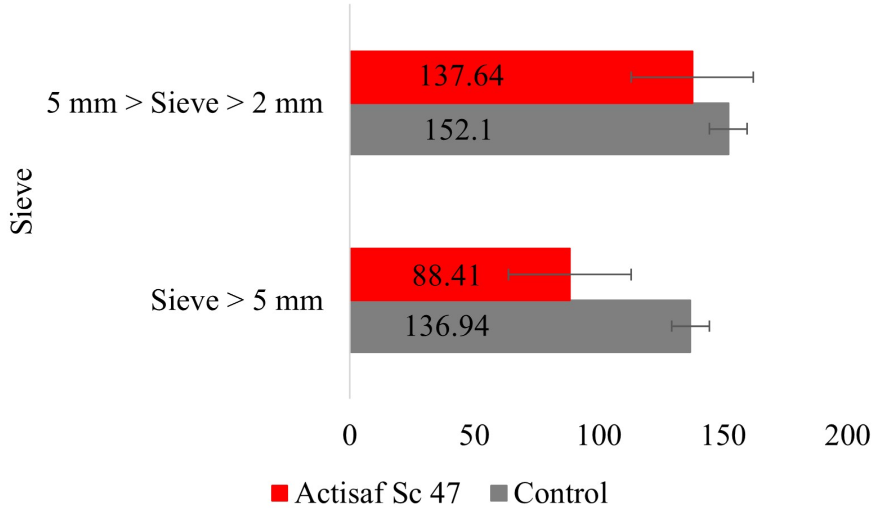

Figure 4. Effect of LYP Actisaf® Sc 47 on PS distribution.

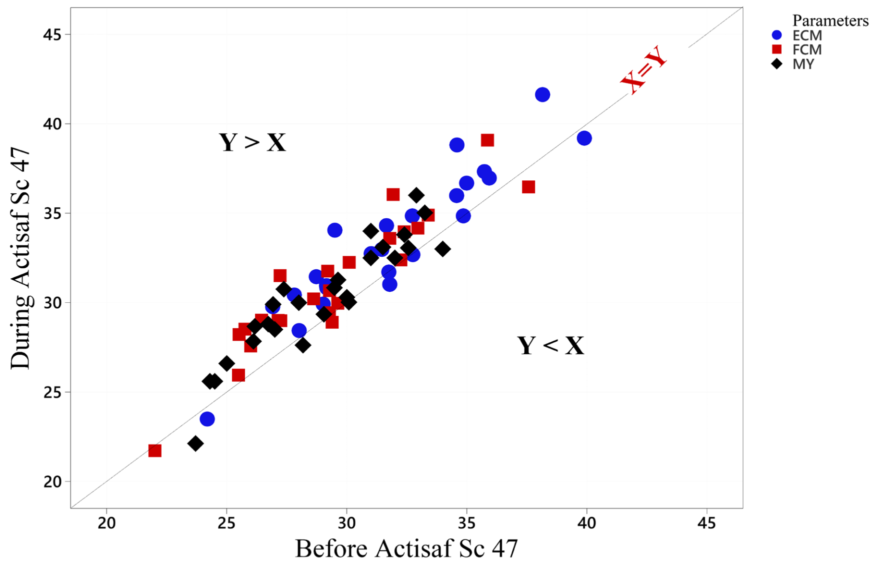

Figure 5. Milk yield (MY), Energy corrected milk (ECM) and fat corrected milk (FCM) production during the different trials. Empty squares represent FCM, empty circles represent ECM and stars represent MY.

effect of LYP supplementation on ECM (31.8 and 33.4 kg/d for Control and LYP group, respectively, P < 0.01; Figure 6).

Fat corrected milk was recorded in 25 trials. Live yeast supplementation increased FCM in 18 trials, reduced FCM in 1 trial and didn't have any effect in 6 trials (Figure 5). The statistical analysis showed significant positive effect of LYP supplementation on FCM (28.77 and 30.30 kg/d for Control and LYP group, respectively, P < 0.01; Figure 6).

3.3. Association between % PS > 5 mm and Milk Parameters

The association between % PS > 5 mm and milk performances was evaluated separately before and during LYP supplementation to validate the feasibility of Digescan™ tool. For both periods, the relationship between % PS > 5 mm and MY was negative and presented in **Figure 7**. The decrease of MY with PS was more important without LYP supplementation than with LYP supplementation as indicated by the slope (0.056 vs. 0.12). The results showed that each 10 points increase in % PS > 5 mm was accompanied by 0.65 and 1.2 kg/d decrease in MY with and without LYP supplementation, respectively.

For ECM, during the two periods, the relationship between PS and ECM was negative and presented in **Figure 8**. The decrease of ECM with PS was more

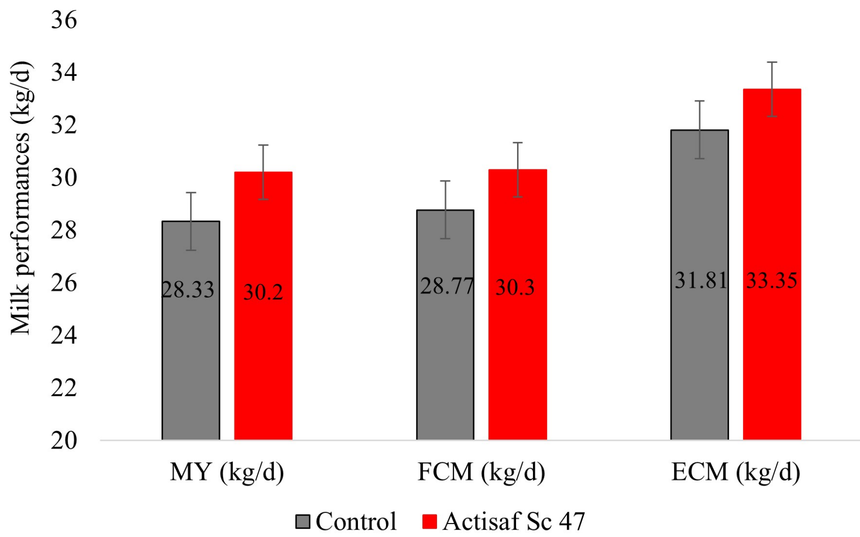

Figure 6. Effect of LYP supplementation of milk performances.

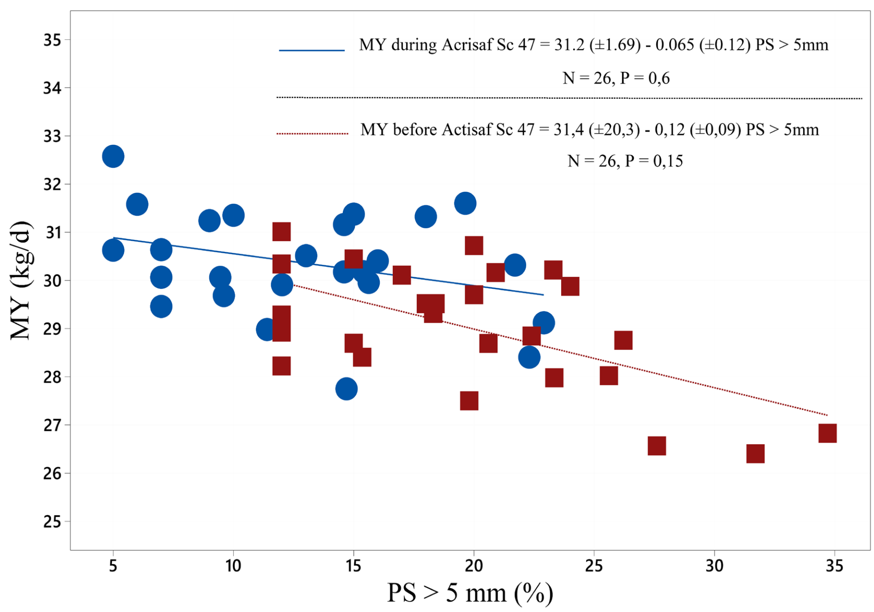

Figure 7. Effect of % of PS > 5 mm (wet basis) on MY before and during LYP Actisaf Sc® 47 distribution.

important without LYP supplementation than with LYP supplementation as indicated by the slope (0.20 vs. 0.25). The results showed that each 10 points increase in % PS > 5 mm was accompanied by 2 and 2.5 kg/d decrease in ECM with and without LYP supplementation, respectively.

For FCM, during the two periods, the relationship between PS and FCM was negative and presented in Figure 9. The decrease of FCM with PS was more important without LYP supplementation than with LYP supplementation as indicated by the slope (0.26 vs. 0.32). The results showed that each 10 points

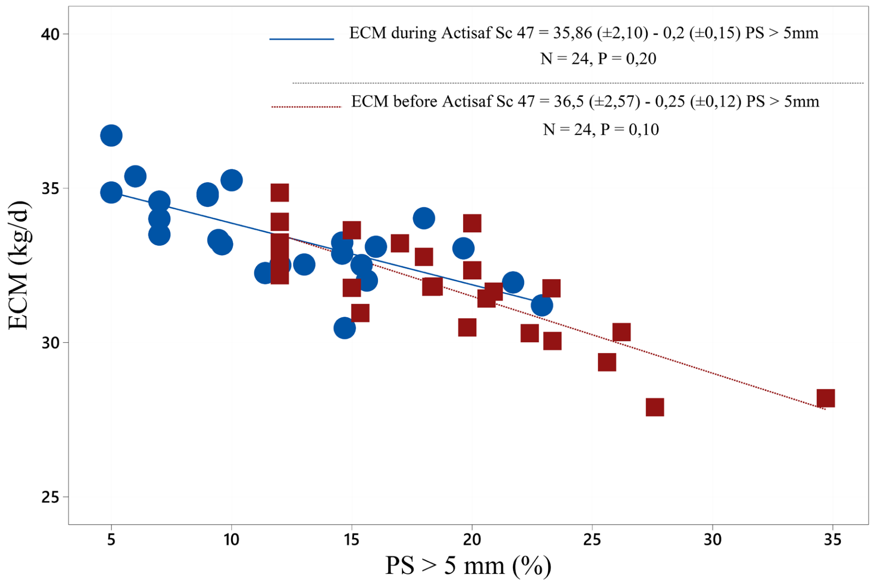

Figure 8. Effect of % of PS > 5 mm (wet basis) on ECM before and during YP Actisaf® Sc 47 distribution.

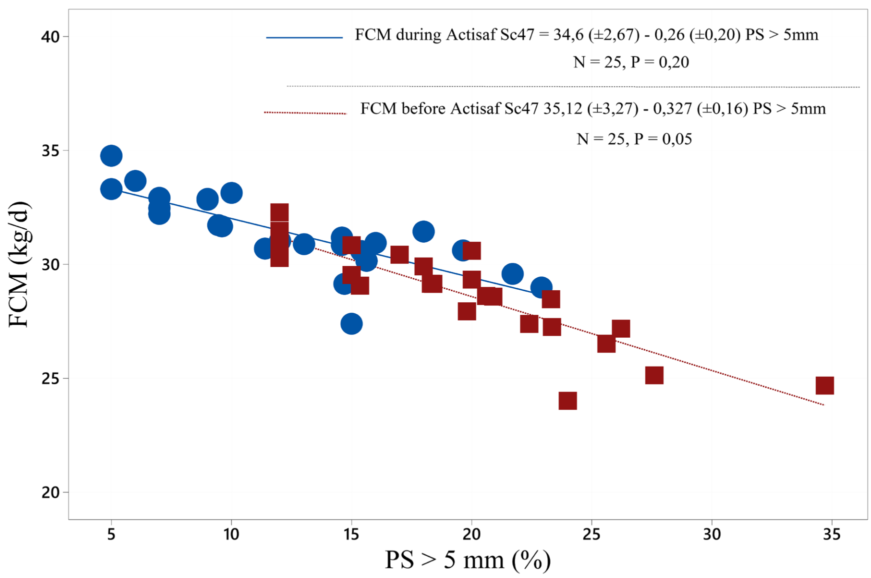

Figure 9. Effect of % of PS > 5 mm (wet basis) on FCM before and during YP Actisaf® Sc 47 distribution.

increase in % PS > 5 mm was accompanied by 2.6 and 3.2 kg/d decrease in FCM with and without LYP supplementation, respectively.

4. Discussion

To describe the feeding situation and its efficiency under field condition, fecal PS evaluation might be a useful tool [21] [22] [23]. The fecal PS distribution has been measured using dry sieving [16] [15] or wet sieving technics [13] [14]. Yet, there is no standard procedure and there is a lack of knowledge regarding the appropriate fecal evaluation method that could provide better assessment of ruminal fermentation and feed valorization. The objective of the current study was to propose a new sieving tool composed of two sieves as indirect method to understand feed valorization under field conditions and to investigate the effect of LYP supplementation on PS distribution and milk parameters in dairy cows.

Total weight of retained fecal particles in the two sieves after rinsing was 290 g for control group and 226 g for LYP. Reported to percentage, these values correspond to 29% and 22.6% for control and LYP, respectively. These values are comparable to those obtained by [21] for NDA separator which varies from 14.66% to 20.37%. In the same way, [24] compared laboratory, monolayer and multilayer (NDA) sieves in three different farms and obtained a range of retained fecal fraction from 12.7% to 18.2% with the laboratory method composed of 6 screens, from 17.8% to 33.8% with monolayer method and from 18.9% to 29.6% of the total fecal weight with multilayer method. Our results agree with ones obtained [14]. Using a wet sieving procedure with 6 screens, they obtained values that ranged from 16.2% to 17.8% of sample larger than 1.18 mm from faeces of lactating cows fed treatment rations with grass hay varying in particle size.

Fecal analysis showed lower weight of PS above 5 mm and between 2 and 5 mm in animals receiving LYP. Our results confirm those obtained by [25] who analyzed fecal PS by using NASCO Digestion Analyzer composed of three sieves (4.8, 2.4 and 1.6 mm). These authors observed smaller fecal particles in cows supplemented with live yeast compared to non-supplemented cows. To our knowledge, except for the publication of [25] there are no published data evaluating the effects of feeding live yeast on fecal PS distribution. The effect of live yeast on reducing fecal particle weight can be explained by better rumen environment and consequently better fiber digestion [26]. In goat, [27] mentioned that as digestibility increases, fecal PS decreases. In this context, [28] evaluated the effect of 0.5 and 1 g/d of live yeast in dairy cow and observed higher fiber digestion for both amounts of yeast compared to control. Many small particles in faeces describe good rumen environment and fermentation [29]. However, many long particles in faeces indicate a diet that has not been properly fermented in the rumen [29]. Hence, many studies have shown a positive effect of live yeast on rumen fermentation [30] [31].

In the current study, we observed positive and significant effect of LYP supplementation on MY. This agrees with several previous researchers [32] [33] [31] [34]. By analyzing data from 14 trials, [33] observed an increase in MY by 1.15 kg/d with LYP supplementation. In a review of 14 experiments, representing 193 cow observations, the increase in milk yield to yeast supplementation was 1.45 L [35]. As observed previously, the use of LYP during our study significantly increased ECM. For example, [36] reported an increase in ECM by 1.4 kg/d as result of LYP supplementation. [37] observed higher ECM (+1.2 kg/d) in their meta-analysis on the effect of yeast supplementation. More recently, [28] detected a + 0.9 and + 2 kg/d increase in ECM when dairy cows were fed 0.5 and 1 g/d of LYP under heat stress conditions.

The positive effect of LYP on FCM observed in our study is in agreement with previous observations. Indeed, Improvement in FCM have been observed in other studies investigating LYP supplementation. [34] reported significant increase in FCM (+6%) when dairy cows were supplemented with 1 g/d of LYP. [38] reported greater FCM content as result of live yeast supplementation in in mid-lactation cow. More recently [28] observed a trend for increased FCM in their study in the effect of feeding LYP at 2 dosages on dairy cow under heat stress conditions. In sheep, [39] reported a numerical increase in FCM when animals were supplemented with 2 g/f of LYP.

Optimizing rumen environment and function is a key to optimize milk performance and feed efficiency. Several studies have shown the positive effect of LYP on the rumen through the stabilization of rumen pH, scavenging oxygen [40] [41], promotion of anaerobic cellulolytic bacteria [26] [41] [42] and increased total volatile fatty acid (VFA) concentration [32] [43] [44]. The observed benefit of supplementing LYP could be a consequence of higher total VFA concentration [32] [45], and their relationship with growth of rumen papillae [46] [47] an increased mitotic index and an inhibition of apoptosis of rumen papillae [48]. All those mechanisms could result in improvement of rumen absorption capacity [49].

The increase of ECM with yeast probiotic observed in our study can be explained by its effect on protein metabolism. [50] indicated that LYP may reduce dietary nitrogen ruminal degradation and consequently increase rumen undegradable protein (RUP) which is positively correlated to ECM as observed by [51]. Indeed, these authors tested different combinations of rumen degradable (RDP) and undegradable proteins and observed an increase in ECM by 16% when RUP increases from 6% to 8% with the same level of RDP and an increase in ECM by 10% when RDP decreases from 10% to 8% with the same level of RUP (6%) [51]. The positive effect of LYP supplementation on FCM can be explained by the positive effect of LYP on fiber digestibility. [52] reported a positive correlation between fiber digestibility and FCM and concluded that per 1-unit increase in fiber digestibility was associated a 0.25 kg increase in FCM.

In the present study, a negative correlation was observed between % of PS > 5 mm and milk parameters with or without LYP supplementation. Although the decrease of milk parameters was not the same with or without LYP supplementation, we observed the same tendency which indicates the feasibility of Digescan as a tool. To our knowledge there are no published data evaluating this association. [53] showed that PS increases when the digestibility of organic matter and crude fiber decreases which could explain the drop of milk parameters with the increase of % of PS > 5 mm [54]. In the same way, [54] established a positive correlation between fiber digestibility which is negatively correlated to fecal PS and MY and FCM. The use of yeast probiotic attenuated the drop in MY, ECM and FCM which indicates the double effect of yeast probiotic on fecal PS and milk performance.

5. Conclusion

The current study has been conducted to develop and promote fecal particle evaluation system by using a wet sieve with or without yeast probiotic supplementation in dairy cow as indicator of feed valorization. The results obtained revealed that fecal particle distribution and milk parameters responded to yeast probiotic supplementation. Therefore, the proposed instrument Digescan™ seems to be a suitable and handy method to understand feed valorization, evaluation of feeding situation and feed efficiency in a global context oriented towards more efficient and sustainable dairy systems. However, more parameters such as chemical composition of the ration, maybe microbiota analysis and digestibility would be needed for further development of the system. The tool and data show that the addition of yeast probiotic reduced large fecal PS and positively influences milk performances in term of MY, ECM and FCM. Effects of diet composition and behavior of feed intake on PS distribution of the feces were not considered.

Acknowledgements

The authors would like to acknowledge all the farmers for their time, technical im-plication, and support during animal trial.

Author's Contribution

This work was carried out in collaboration among all authors. Author LF, MB, RG and VN designed the trials and collected the data. NS and HL organized the data and performed the statistical analysis. Author NS wrote the first draft of the manuscript. Author VN managed supported data collection. All authors read and approved the final manuscript.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Linn, J. (2006) Feed Efficiency: Its Economic Impact in Lactating Dairy Cows. *WCDS Advances in Dairy Technology*, **18**, 19-28.

[2] Connor, E.E. (2014) Invited Review: Improving Feed Efficiency in Dairy Production: Challenges and Possibilities. *Animal*, **9**, 395-408. https://doi.org/10.1017/S1751731114002997

[3] McAuliffe, S., Mee, J.F., Lewis, E., Galvin, N. and Hennessy, D. (2022) Feeding System Effects on Dairy Cow Rumen Function and Milk Production. *Animals*, **12**, Article No. 523. https://doi.org/10.3390/ani12040523

[4] Bergman, E.N. (1990) Energy Contributions of Volatile Fatty Acids from the Gastrointestinal Tract in Various Species. *Physiological Reviews*, **70**, 567-590. https://doi.org/10.1152/physrev.1990.70.2.567

[5] Burdick, S.N.C., Broadway, P.R. and Carroll, J.A. (2021) Influence of Yeast Products on Modulating Metabolism and Immunity in Cattle and Swine. *Animals* (*Basel*), **11**, Article No. 371. https://doi.org/10.3390/ani11020371

[6] Chaucheyras-Durand, F., Walker, N.D. and Bach, A. (2008) Effects of Active Dry Yeasts on the Rumen Microbial Ecosystem: Past, Present and Future. *Animal Feed Science and Technology*, **145**, 5-26. https://doi.org/10.1016/j.anifeedsci.2007.04.019

[7] Chumpawadee, S., Chantiratikul, A. and P. Chantiratikul, P. (2007) Chemical Composition and Nutritional Evaluation of Energy Feeds for Ruminant Using *In-Vitro* Gas Production Technique. *Pakistan Journal Nutrition*, **6**, 607-612. https://doi.org/10.3923/pjn.2007.607.612

[8] Cooke, B.C. (1988) Evaluations of Feed for Ration Formulation. *Proceedings of the Nutrition Society*, **47**, 135-141. https://doi.org/10.1079/PNS19880023

[9] Khorrami, B., Kheirandish, P., Zebeli, Q. and Castillo-Lopez, E. (2022) Variations in Fecal pH and Fecal PS Due to Changes in Dietary Starch: Their Potential as an On-Farm Tool for Assessing the Risk of Ruminal Acidosis in Dairy Cattle. *Research Veterinary Science*, **152**, 678-686. https://doi.org/10.1016/j.rvsc.2022.10.001

[10] Peiretti, G.P. (2020) Introduction to the Special Issue: *In Vitro* Digestibility in Animal Nutritional Studies. *Animals*, **10**, 929.

[11] Lopez, S. (2005) *In Vitro* and *in Situ* Techniques for Estimating Digestibility. In: Dijsktra, J., Forbes, J.M. and France, J., Eds., *Quantitative Aspects of Rumen Digestion and Metabolism*, 2nd Edition, CAB International, Wallingford, 87. https://doi.org/10.1079/9780851998145.0087

[12] Khan, M.A., Mahr, U.N.-N. and Sarwar, M. (2003) Techniques Measuring Digestibility for the Nutritional Evaluation of Feeds. *International Journal of Agriculture & Biology*, **1**, 91-94.

[13] Rinne, M., Huhtanen, P. and Jaakkola, S. (2002) Digestive Processes of Dairy Cows Fed Silages Harvested at Four Stages of Grass Maturity. *Journal Animal Science*, **80**, 1986-1998. https://doi.org/10.2527/2002.8071986x

[14] Maulfair, D.D., Fustini, M. and Heinrichs, A.J. (2011) Effect of Varying Total Mixed Ration Particle Size on Rumen Digesta and Fecal Particle Size and Digestibility in Lactating Dairy Cows. *Journal Dairy Science*, **94**, 3527-3536. https://doi.org/10.3168/jds.2010-3718

[15] Jalali, A.R., Weisbjerg, M.R., Nadeau, E., Randby, A.T., Rustas, B.O., Eknas, M. and Norgaard, P. (2015) Effects of Forage Type, Animal Characteristics and Feed Intake on Faecal Particle Size in Goat, Sheep, Llama and Cattle. *Animal Feed Science and*

Technology, **208**, 53-65. https://doi.org/10.1016/j.anifeedsci.2015.07.003

[16] Rustas, B.O., Norgaard, P., Jalali, A.R. and Nadeau, E. (2010) Effects of Physical Form and Stage of Maturity at Harvest of Whole-Crop Barley Silage on Intake, Chewing Activity, Diet Selection and Faecal Particle Size of Dairy Steers. *Animals*, **4**, 67-75. https://doi.org/10.1017/S1751731109990887

[17] Hall, M.B. (2005) Using Manure Evaluation as a Diagnostic Tool for Ration Evaluation. In: *Proceedings Fedd and Nutrition Management*, Virginia Polytechnic Institute and State University, Blacksburg, 67-74.

[18] Tyrrell, H.F. and Reid, J.T. (1965) Prediction of the Energy Value of Cow's Milk. *Journal Dairy Science*, **48**, 1215-1223. https://doi.org/10.3168/jds.S0022-0302(65)88430-2

[19] Gains, W.L. (1928) The Energy Basis of Measuring Milk Yield in Dairy Cows. University of Illinois, Champaign, Agriculture Experiment Station, Bulletin No. 308.

[20] Sauvant, D., Schmidely, P., Daudin, J.J. and St-Pierre, N.R. (2008) Meta-Analyses of Experimental Data in Animal Nutrition. *Animal*, **2**, 1203-1214. https://doi.org/10.1017/S1751731108002280

[21] Kjlak, K., Heinrichs, B.S. and Heinrichs, A.J. (2019) Fecal Particle Dry Matter and Fiber Distribution of Heifers Fed ad Libitum and Restricted with Low and High Forage Quality. *Journal Dairy Science*, **102**, 4694-4703. https://doi.org/10.3168/jds.2018-15457

[22] Clauss, M., Hume, I.D. and Hummel, J. (2010) Evolutionary Adaptations of Ruminants and Their Potential Relevance for Modern Production Systems. *Animal*, **4**, 979-992. https://doi.org/10.1017/S1751731110000388

[23] Kornfelt, L.F., Weisbjerg, M.R. and Nørgaard, P. (2013) Effect of Harvest Time and Physical Form of Alfalfa Silage on Chewing Time and PS Distribution in Boli, Rumen Content and Faeces. *Animal*, **7**, 232-244. https://doi.org/10.1017/S1751731112001437

[24] Carta, P. (2010) The Physically Effective Fiber of total Mixed Rations and Its Effects on Dairy Cow Performances. PhD Thesis. Department of Animal Science, Univ. Sassari, Sassari.

[25] Keimer, B., Ilka Bockhop, I., Schlagheck, A., Schön, H.G. and Westendarp, H. (2016) Effects of Live Yeast on Particle Size Distribution of Feces and Performance Parameters in Dairy Cows Fed on Starch-Rich Diets. *Veterinarija ir Zootechnika* (*Veterinary Medicine and Zootechnics*), **73**, 64-67.

[26] Marden, J.P., Juilen, C., Monteils, V., Auclair, E., Moncoulon, R. and Bayourthe, C. (2008) How Does Live Yeast Differ from Sodium Bicaronate to Stabilize Ruminal pH in high-Yielding Dairy Cows? *Journal Dairy Science*, **91**, 3528-3535. https://doi.org/10.3168/jds.2007-0889

[27] Santoso, S.A.B., Puspitasari, G., Muktiani, A.S. and Purnomoadi, A. (2015) A Study on the Use of Fecal Characteristics for Feed Digestibility Determination in Goat. *Journal of the Indonesian Tropical Animal Agriculture*, **40**, 59-67. https://doi.org/10.14710/jitaa.40.1.59-67

[28] Perdomo, M.C., Marsola, R.S., Favoreto, M.G., Adesogan, Staples, A.C.R. and Santos, J.E.P. (2020) Effects of Feeding Live Yeast at 2 Dosages on Performance and Feeding Behavior of Dairy Cows under Heat Stress. *Journal of Dairy Science*, **103**, 325-339. https://doi.org/10.3168/jds.2019-17303

[29] Nørgaard, P., Husted, S. and Ranvig, R. (2004) Effect of Supplementation with Whole Wheat or Whole Oat Grains on the Dimensions of Faeces Particles from

Lambs. *Journal Animal and Feed Science*, **13**, 175-178.
https://doi.org/10.22358/jafs/73770/2004

[30] Sousa, D.O., Oliveira, C.A., Velasquez, A.V., Souza, J.M., Chevaux, E., Mari, L.J. and Silva, L.F.P. (2018) Live Yeast Supplementation Improves Rumen Fiber Degradation in Cattle Grazing Tropical Pastures throughout the Year. *Animal Feed Science and Technology*, **236**, 149-158. https://doi.org/10.1016/j.anifeedsci.2017.12.015

[31] Desnoyers, M., Giger-Reverdin, S., Bertin, G., Duveaux-Ponter, C. and Sauvant, D. (2008) Meta-Analysis of the Influence of *Saccharomyces cerevisiae* Supplementation on Ruminal Parameters and Milk Production of Ruminants. *Journal Dairy Science*, **92**, 1620-1632. https://doi.org/10.3168/jds.2008-1414

[32] Kumprechtova, D., Illek, J., Juilen, C., Homolka, P., Jancik, F. and Auclair, E. (2019) Effect of Live Yeast (*Saccharmyces cerevisiae*) Supplementation on Rumen Fermentation and Metabolic Profile of Dairy Cows in Early Lactation. *Journal Animal Physiology Animal Nutrition*, **103**, 447-455. https://doi.org/10.1111/jpn.13048

[33] De Ondarza, M.B., Sniffen, C.J., Dussert, L., Chevaux, E., Sullivan, J. and Walker, N. (2010) CASE STUDY: Multiple-Study Analysis of the Effect of Live Yeast on Milk Yield, Milk Component Content and Yield, and Feed Efficiency. *The Professional Animal Scientist*, **26**, 661-666. https://doi.org/10.15232/S1080-7446(15)30664-1

[34] Moallem, U., Lehrer, H., Livshitz, L., Zachut, M. and Yakoby, S. (2009) The Effects of Live Yeast Supplementation to Dairy Cows during the Hot Season on Production, Feed Efficiency, and Digestibility. *Journal Dairy Science*, **92**, 343-351.
https://doi.org/10.3168/jds.2007-0839

[35] Sniffen, C.J., Chaucheyras-Durand, F., Ondarza, M.B. and Donaldson, G. (2007) Predicting the Impact of Live Yeast Strain on Rumen Kinetics and Ration Formulation. *Proceedings of the South West Nutrition and Management Conference*, Phoenix, 22-23 February 2007, 53-59.
http://cals-cf-calsnet.arizona.edu/animsci/ansci/swnmc/papers/2004/4-sniffen.pdf

[36] Tristant, D. and Moran, C.A. (2015) The Efficacy of Feeding a Live Probiotic Yeast, Yea-Sacc, on the Performance pf Lactating Dairy Cows. *Journal of Applied Animal Nutrition*, **3**, e12. https://doi.org/10.1017/jan.2015.10

[37] Tricarico, J., Harrison, G. and Johnston, J. (2006) Modeling Yea-Sacc®1026 Effect on Ruminal Function and Performance in Lactating Dairy Cattle within the Framework of the CPM-Dairy Ration Analyzer. *Nutritional Biotechnology in the Feed and Food Industries*, *Alltech's 22nd Annual Symposium* (*Poster Session*), Lexington, 23-26 April 2006, 72.

[38] Salvati, G.G.S., Morais Júnior, N.N., Melo, A.C.S., Vilela, R.R., Cardoso, F.F., Aronovich, M., Pereira, R.A.N. and Pereira, M.N. (2015) Response of Lactating Cows to Live Yeast Supplementation during Summer. *Journal of Dairy Science*, **98**, 4062-4073.
https://doi.org/10.3168/jds.2014-9215

[39] Mavrommatis, A., Christina, M., Christodoulou, C., Dimitris Karabinas, D., Valentin, N., George, Z. and Eleni, T. (2020) Dietary Supplementation of a Live Yeast Product on Dairy Sheep Milk Performance, Oxidative and Immune Status in Peripartum Period. *Journal Fungi*, **6**, Article No. 334.
https://doi.org/10.3390/jof6040334

[40] Jouany, J.-P. (2006) Optimizing Rumen Functions in the Close-Up Transition Period and Early Lactation to Drive Dry Matter Intake and Energy Balance in Cows. *Animal Reproduction Science*, **96**, 250-264.
https://doi.org/10.1016/j.anireprosci.2006.08.005

[41] Chaucheyras-Durand, F. and Fonty, G. (2002) Yeasts in Ruminant Nutrition.

Expériences with Live Yeast Product. *Kraftfutter*, **85**, 146-150.

[42] Jiang, Y., Ogunade, I.M., Arriola, K.G., Qi, M., Vyas, D., Staples, C.R. and Adesogan, A.T. (2017) Effects of the Dose and Viability of *Saccharomyces cerevisiae*. 2. Ruminal Fermentation, Performance of Lactating Dairy Cows, and Correlations between Ruminal Bacteria Abundance and Performance Measures. *Journal of Dairy Science*, **100**, 8102-8118. https://doi.org/10.3168/jds.2016-12371

[43] Zhu, W., Wei, Z. and Xu, N. (2017) Effects of *Saccharomyces cerevisiae* Fermentation Products on Performance and Rumen Fermentation and Microbiota in Dairy Cows Fed a Diet Containing Low Quality Forage. *Journal of Animal Science and Biotechnology*, **8**, 36. https://doi.org/10.1186/s40104-017-0167-3

[44] Hasunuma, T., Uyeno, Y., Akiyama, K., Hashimura, S., Yamamoto, H., Yokokawa, H., Yamaguchi, T., Itoh, M., Mizuguchi, H., Sato, S., Hirako, M.S. and Kushibiki, S. (2016) Consecutive Reticular pH Monitoring in Dairy Cows Fed Diets Supplemented with Active Dry Yeast during the Transition and Mid-lactation Periods. *Animal Feed Science and Technology*, **221**, 215-225. https://doi.org/10.1016/j.anifeedsci.2016.09.002

[45] Oh, J., Harper, M., Melgar, A., Compart, D.M., Paulus and Hristov, A.N. (2019) Effects of *Saccharomyces cerevisiae*-Based Direct-Fed Microbial and Exogenous Enzyme Products on Enteric Methane Emission and Productivity in Lactating Dairy Cows. *Journal of Dairy Science*, **102**, 6065-6075. https://doi.org/10.3168/jds.2018-15753

[46] Sakata, T. (2004) Effects of Short-Chain Fatty Acids on the Proliferation of Gut Epithelial Cells *in Vivo*. In: Cummings, T.S., Ohn, H. and Rombeau, J.L., Eds., *Effects of Short-Chain Fatty Acids on the Proliferation of Gut Epithelial Cells in Vivo*, Cambridge University Press, Cambridge, 289.

[47] Blottiere, H.M., Buecher, B., Galmiche, J.-P. and Gherbut, C. (2003) Molecular Analysis of the Effect of Short-Chain Fatty Acids on Intestinal Cell Proliferation. *Proceeding Nutrition Society*, **62**, 101-106. https://doi.org/10.1079/PNS2002215

[48] Abdelli, A., Besbaci, M., HAnsali, S., Rahmani, B., Belabdi, I., Enjalbert, G. and Raboisson, D. (2022) Association between Yeast Product Feeding and Milk Production of Lactating Dairy Cows: Multilevel Meta-Analysis and Meta-Regression. *Animal Feed Science and Technology*, **285**, Article ID: 115240. https://doi.org/10.1016/j.anifeedsci.2022.115240

[49] Bannink, A., Gerrits, W.J.J., France, J. and Dijkstra, J. (2012) Variation in Rumen Fermentation and the Rumen Wall during the Transition Period in Dairy Cows. *Animal Feed Science and Technology*, **172**, 80-94. https://doi.org/10.1016/j.anifeedsci.2011.12.010

[50] Julien, C., Marden, J.P., Auclair, E., Moncoulon, R., Cauquil, L., Peyraud, J.L. and Bayourthe, C. (2015) Interaction between Live Yeast and Dietary Rumen Degradable Protein Level: Effects on Diet Utilization in Early-Lactating Dairy Cows. *Agricultural Sciences*, **6**, 1-13. https://doi.org/10.4236/as.2015.61001

[51] Kaufman, J.D., Kassube, K.R. and Rius, A.G. (2017) Lowering Rumen-Degradable Protein Maintained Energy-Corrected Milk Yield and Improved Nitrogen-Use Efficiency in Multiparous Lactating Dairy Cows Exposed to Heat Stress. *Journal Dairy Science*, **100**, 8132-8145. https://doi.org/10.3168/jds.2017-13026

[52] Oba, M. and Allen, M.S. (1999) Evaluation of the Importance of the Digestibility of Neutral Detergent Fiber from Forage: Effects on Dry Matter Intake and Milk Yield of Dairy Cows. *Journal Dairy Science*, **82**, 589-596. https://doi.org/10.3168/jds.S0022-0302(99)75271-9

[53] Grenet, E. (1966) Les particules végétales des fèces de mouton. *Annales de zootechnie*, *INRA/EDP Sciences*, **15**, 303-312. https://doi.org/10.1051/animres:19660401

[54] Phesatcha, B., Phesatcha, K.B., Thao, T.N. and Wanapat, M. (2021) Feed Intake and Nutrient Digestibility, Rumen Fermentation Profiles, Milk Yield and Compositions of Lactating Dairy Cows Supplemented by *Flemingia macrophylla* Pellet. *Tropical Animal Science Journal*, **44**, 288-296. https://doi.org/10.5398/tasj.2021.44.3.288