Dairy Industry Sustainability- Has Progress Been Made?

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Sustainability is a current topic of discussion, debate, controversy, and opportunity for the dairy industry. Social, environmental, and economics are the 3 pillars of sustainability (Segerkvist et al., 2020). A recent survey indicated that >50% of consumers purchasing dairy products are interested in the availability of sustainability information (Schiano e. al., 2020). Animal welfare, carbon footprint and greenhouse gas emissions were some of the attributes of sustainability listed in this report. Other reports include water and air quality as concerns. Consumer perceptions of dairy management practices also need to be recognized and considered as the industry moves ahead to address sustainability (Naspetti et al., 2021; Widmar et al., 2017). Review papers on U.S. dairy sustainability are available (Martin et al., 2017: von Keyserlingk et al., 2013)

Changes in the U.S. dairy industry between 2007 and 2017 have been quantified (Capper and Cady, 2019). Total dairy cow numbers increased by 2.1% while energy corrected milk (ECM) per cow increased by 22%. Total U.S. ECM production increased by 25%. The authors reported changes in resource use and emissions based on producing 1 million metric tons (MMT) of ECM. The number of cows needed in 2017 was 74.8% of the cows required in 2007. Resource use in 2017 compared with 2007 was 17% less feed, 21% less land and 30% less water. The dairy industry in 2017 produced 21% less manure compared with 2007. Manure nitrogen and phosphorus excretions were 17 and 14% less than the 2007 values. Total greenhouse gas emissions in 2017 were 19% less than the 2007 values. Methane emission were 19% lower than 2007. Carbon footprint decreased by 19%. These results indicate significant progress by the dairy industry in reducing environmental impact over this time when expressed on a 1 MMT basis while increasing milk production.

A second paper examined the changes in the California dairy industry between 1964 and 2014 (Naranjo et al., 2020). Daily milk production per cow increased by 129% over the 50-year period. Water and land use needed to produce 1 kg of ECM decreased by 89.9 and 89.7%. Methane emitted per kg of ECM decreased by 56%. The authors also calculated the shift in total carbon dioxide equivalent emissions per kg of ECM. The value in 2017 was 1.16 compared with 2.11 in 1964.

Progress in New York

The New York dairy and feed industry have a long history of being environmentally conscious and responsible. The emphasis on nutrient management planning and precision feeding are examples. Several New York and Northeast dairy herds have been recognized for their sustainability efforts. Table 1 lists herds recognized for outstanding dairy farm sustainability by the Innovation Center for U.S. Dairy. Noblehurst Farms were recognized for an outstanding achievement in community partnerships award in 2016 from the Innovation Center for U.S. dairy. Table Rock Farm received the 2021 Leopold Conservation award from the New York AEM program in 2021. Lamb Farms and the Western New York Crop Management Association were recognized as a 2021 4R advocate by the Fertilizer Institute.

Table 1. Northeast Dairy Sustainability Award Recipients

Year	Farm	State
2012	Blue Spruce Farm	Vermont
2014	Sensenig Dairy	Pennsylvania
2015	Oregon Dairy	Pennsylvania
2018	E-Z Acres	New York
2018	Reinford Farms	Pennsylvania
2020	Twin Birch Dairy	New York
2021	Goodrich Farm	Vermont
2021	Red Sunset Farm	Pennsylvania

[a] Awards from the Innovation Center for U.S. Dairy

A project was done to assess changes in milk production, ration N and P levels, and nutrient excretion on New York fairy farms between 1999 and 2019 (Chase and Reed, 2021a, b). This study was done in cooperation with the Northeast Agribusiness and Feed Alliance. The 1999 diet was 50% forage with a 1:1 ratio of corn silage to alfalfa silage (DM basis). Diet NDF was 38% and was 19% starch. The 2019 diet was 60% forage with 60% of the forage as corn silage and 40% alfalfa silage. Ration NDF was 35% and starch was 26%. Milk production per cow was 40% higher in 2019 while cow numbers dropped by 10%. Total New York milk production during this period increased by 26%. Total manure nitrogen and phosphorus excretion to the environment were reduced by 8 and 20%. Ammonia potential and methane emissions were 17 and 3% lower in 2019. These results indicate that the New York dairy and feed industry have decreased the environmental impact of the dairy industry while increasing milk production.

Trials have also been conducted on commercial dairy herds to evaluate changes in diet CP on nutrient excretion and profitability. A study in western New York used 2 dairy herds over an 8-month period (Higgs et al., 2012). This trial was done in cooperation with the nutritionists working with the herd. Diets fed were evaluated and reformulated using the CNCPS model. Diet CP was reduced about 1 unit in each herd. Daily manure nitrogen output was lowered by 12 and 6%. Income over purchased feed cost increased by $1.27 per cow per day in one herd and $0.27 in the second herd.

A second trial was done over a 3-year period using 8 herds in the Upper Susquehanna watershed to evaluate the impact of implementing a precision feed management program (Van Amburgh et al., 2019). This trial was conducted in cooperation with the nutritionists working in these herds. Diets were formulated by the herd nutritionist and evaluated with the CNCPS model. Diet changes were made after discussion between the herd nutritionist and the project leader. Milk production increased by 4 pounds per cow per day. Diet CP decreased from 17.4 to 15.8%. Manure nitrogen excretion decreased by 14%. Income over purchased feed cost increased by $137 per cow per year.

Table 2. Changes in New York – 1999 to 2019

Item	1999	2019	Change
Milk, lbs./cow/year	17,176	24,118	+40.4%
Number of dairy cows	701,000	627,000	-10,5%
Milk, lbs./cow/day	47	66	+40.4%
Total NY Milk Production, billion pounds	12	15.1	+25.8%
Ration DMI, lbs./day	38.6	48.3	+25.1%
Ration CP, % of DM	18.5	16.5	-10.8%
Ration P, % of DM	0.48	0.39	-18.8%
Ration N Intake, g/cow/day	520	578	+11.1
Milk N, g/cow/day	112	158	+41.1
Manure N, g/cow/day	408	420	+2.9%
NY Total Manure N, tons/year	114,964	105,649	-8.1%
Ration P Intake, g/day	84	85	+1.2%
Milk P, g/day	19	27	+42%
Manure P, g/day	65	58	-10.8%
NY Total Manure P, tons/year	18,331	14,640	-20.1%
Ammonia Potential Emissions, g/cow/day	145	134	-7.6%
Total NY Potential Ammonia Emissions, tons/year	40895	33803	-17.3%
Methane Emissions, g/cow/day	389	420	+8%
Methane Emissions, g/lb. of milk	8.3	6.4	-23%
Total NY Methane emissions, tons/year	109,625	105,890	-3.4%

Whole farm mass nutrient balance (WFMB) is another tool that can be used to assess the impact of dairy farms on the environment. Changes in WFMB for 91 dairy herds in the Upper Susquehanna watershed between 2004 and 2013 were reported (Cela et al., 2017). WFMB for nitrogen decreased by 50% while phosphorus was 51% lower. If a nitrogen fixation estimate was included, the nitrogen WFMB was 29% lower in 2013.

Decreases in feed nitrogen and phosphorus imports to the farm were a primary factor for the change in WFMB.

Co-Product Feeds in Dairy Rations

The use and incorporation of co-product feeds in ruminant and dairy rations has been an accepted and widely used practice for many years. The commercial feed industry is a primary user of co-product feeds from grain milling, ethanol production, beer brewing and the rendering industry. Many commercial grain mixes and protein supplements are primarily composed of co-product ingredients. There are also an increasing number of dairy producers that purchase, store, and utilize co-products in their on-farm mixed diets. The use of co-product ingredients is attractive since they are often economically priced sources of energy, protein, fiber, and fat. Co-product feeds have been used to replace both concentrates and some forages in dairy rations. A recent paper had a list of 363 unusual and byproduct feeds that could be utilized in ruminant rations (Waller, 2020). Utilizing co-product feeds in rations decreases the need to landfill or incinerate these feeds. It was estimated that 137 million tons of co-products were available in an annual basis in the U.S. (Knapp, 2015). Less carbon dioxide was released when co-products were used in diets than if they were incinerated (Van Amburgh et al., 2019). California workers reported that co-product feeds comprised 41% of total diet dry matter. Co-product feeds were 26% of total diet dry matter in 46 high producing dairy herds (Chase, 2019). A summary of 91 diets from 70 herds found that co-product feeds were 31% of the total diet (Ven Amburgh et sl., 2019). The range was 9 to 57%.

Conversion of Human Inedible Feeds

One approach that deserves more attention is the role of ruminants in converting human inedible feeds into human edible foods. A key factor in this conversion is the capability of rumen microorganisms to convert nonprotein nitrogen compounds, like urea, into protein and amino acids (Loosli et al., 1949). A second factor is the ability of rumen bacteria and fungi to produce cellulase enzymes that can break the β 1-4 glycosidic linkage of cellulose (Van Soest, 1982: Weimer, 1996). Human and mammalian digestive enzymes are not able to break this linkage. Since cellulosic carbohydrates are a large potential supply of nutrients, this provides ruminants the mechanism to convert these carbohydrates into animal products for use in human diets.

Calculating the quantity of human edible protein (HEP) produced relative to the quantity of human edible protein consumed (HEC) is one approach that can be used (Wilkinson, 2011; Ertl et al., 2015). A ratio >1 of HEP/HEC indicates that more human edible protein is produced than consumed by an animal. A paper from Sweden compared a cereal grain, soybean meal grain mix with 3 different co-product feeding strategies (Karlsson et al., 2018). The HEP/HEC ratio for the cereal-based diet was 0.73 compared with 2.56 to 2.68 for the co-product diets. Another trial replaced cereals and pulses with byproduct feeds (Ertl et al., 2015). The HEP/HEC ratio was 1.6 on the control diet snd 4.27 for the byproduct diet. When this calculation was done on an energy basis, the ratio for the control diet was 1.3 compared with 5.55 for the byproduct diet. A trial with late lactation dairy cows was done substituting co-product feeds for corn grain snd soybean meal (Hall and Chase, 2014). The HEP/HEC ratio was 0.78 for the diet with corn and soybean meal versus 1.94 for the co-product diet.

Refinements to this approach have been proposed. One is to include digestible amino acids in calculating the efficiency of protein conversion (Ertl et al., 2016; Patel et al., 2017). This is important since the animal proteins produced are higher in biological value than most plant proteins (Oltjen and Beckett, 1996; Patel et al., 2017). One paper reported that animal proteins have a biological value 1.4 times higher than plant proteins (Pimental and Pimental, 2003).

A second refinement is to combine both the nutrient composition and the portion of HEP that the food industry demands (Tricarico, 2016). In this approach, the human edible portion of the feed is calculated as 1-NDF. This is termed the composition coefficient and assumes that the fiber fraction is not usable by humans. If a feed has an NDF>30%, then the composition coefficient is set to 0. The demand coefficient is determined by multiplying the composition coefficient by the percent of the food used for domestic use. As an example, the composition coefficient of corn grain is 0.91. Food use of corn grain was 12% of the total U.S. grain production in 2015. This result in a demand coefficient of 0.11. In an example diet, 20% of the total dry matter was human inedible. When the demand coefficient was used, this decreased to 2.2%.

. There continues to be a perception that feeds consumed by dairy cows are competing with humans for food resources. On a global basis, it was reported that 86% of the feed consumed by ruminants was not edible by humans (Mottet et al., 2017). The California group estimated that 82% of the feed consumed by dairy cows was inedible by humans (California Dairy Research Foundation, 2016). Average human inedible portion of the ration was 84% of the total dry matter intake for 46 dairy herds not feeding high moisture shelled corn (Chase, 2019). The range was 73.5 to 97.8 % of the total ration dry matter as human inedible feed. These herds averaged 59 pounds of dry matter intake and 110 pounds of milk per cow per day.

Whole Farm Considerations

The integration of animal, land resources, crops, manure management and economics is essential in evaluating and developing strategies for dairy farm sustainability. Developing forage-based diets without considering the capability of the land resources and cropping system to supply the needed forage quantities and qualities is a problem. An example of the whole farm approach is a paper simulating best management practices (BMP) on a 1,500 cow New York dairy (Veltman et al., 2018). The simulation was done using the Integrated Forage System Model (Rotz et al., 2016). A base farm was defined in terms of crop acres, housing, management, field management and diets. Several best management practices were examined to reduce the environmental impact of the farm. Application of several BMP's resulted in a projected 11% increase in milk production and a 27% increase in net return per cow. The reactive

N and total farm losses were by 41 and 46% lower. Farm carbon footprint was 41% lower with the use of the BMP's.

Summary

1. The dairy industry has made significant progress in reducing environmental impact while increasing milk production. The carbon footprint has also been reduced
2. Using co-product feeds in dairy diets decreases disposal needs and costs by incineration or in landfills.
3. Dairy cows and other ruminants can convert human inedible feeds into high quality foods (milk, meat) for human diets.
4. The dairy industry needs to be more proactive making this information available to consumers.
5. The use of whole farm integrated models is essential to continue the progress made to date. The various component of the dairy enterprise must work in unison to integrate milk production, environmental considerations, and profitability.

References

Capper, J.L. and R.A. Cady. 2019. The effects of improved performance in the U.S. dairy industry on environmental impacts between 2007 and 2017. J. Anim. Sci. 1-1

Cela, S., Q.M. Ketterings, M. Soberon, C. Rasmussen and K.J. Czymmek. 2017. Upper Susquehanna watershed and New York State improvements in nitrogen and phosphorus mass balances of dairy farms. J. of Soil and Water Conservation. 72(1)1-11.

Chase, L.E. 2019. What do high producing herds really feed? Proc. Cornell Nutr. Conf. Syracuse, NY. Pp:225-230.

Chase, L.E. and K.F. Reed. 2021a. Science and industry work to improve phosphorus management on New York dairy farms. Animal Science Publication Series No.253. Department of Animal Science, Cornell University. Ithaca, NY. https://hdl.handle.net/1813/10767

Chase, L.E. and K.F. Reed. 2021b. Science and industry work to improve nitrogen management on New York dairy farms. Animal Science Publication Series No. 255. Department of Animal Science, Cornell University. Ithaca, NY. https://hdl.handle.net/1813/103766

Ertl, P., W. Knaus and W. Zollitsch. 2016. An approach to including protein quality when assessing the net contribution of livestock to the human food supply. Animal. 10:1883-1889.

Ertl, P., Q. Zebell, W. Zollitsch and W. Knaus. 2015. Feeding by-products completely replaced cereals and pulses in dairy cows and enhanced edible feed conversion ratio. J. Dairy Sci. 98:1225-1233.

Feil, A.A., D. Schreiber, V. Haetinger, A.M. Haberkamp, J.I. Kist, C. Rempel, A.E. Maehler, M.C. Gomes and G.R. da Silva. 2020. Sustainability in the dairy

industry: a systematic literature review. Environmental Science and Pollution Research. 27:33527-33542.
Gilson, G. 2020. Looking for high-production and sustainable diets for lactating cows: A survey in Italy. J. Dairy Sci: 103:4863-4873.
Hall, M.B. and L.E. Chase. 2014. Responses of late-lactation cows to forage substitutes in low-forage diets supplemented with by-products. J. Dairy Sci. 97:3042-3052.
Higgs, R.J., L.E. Chase, and M.E. Van Amburgh. 2012. Case study: Application and evaluation of the Cornell Net Carbohydrate and Protein System as a tool to improve nitrogen utilization in commercial dairy herds. The Professional Animal Scientist. 28:370-378.
Karlsson, J., R. Sporndly, M. Lindberg and K. Holtenius. 2018. Replacing human-edible feed ingredients with by-products increases net food production efficiency in dairy cows. J. Dairy Sci. 101:7146-7145.
Knapp, J.R. 2015. Dairy sustainability -using the real facts. Proc. Tri-State Nutr. Conf. Fort Wayne, IN. pp:135-141.
Loosli, J.K., H.H. Williams, W.E. Thomas, F.H. Ferris, and L.A. Maynard. 1949. Synthesis of amino acids in the rumen. Science 110:144-145.
Martin, N.P., M.P. Russelle, J.M. Powell, C.J. Sniffen, S.I. Smith, J.M. Tricarico and R.J. Grant. 2017. Invited review: Sustainable forage and grain crop production for the US dairy industry. J. Dairy Sci. 100:9479-9494.
Mottet, A., C. de Haan, A. Falcucci, G. Tempio, C. Opio and P. Gerber. 2017. Livestock: On our plates or eating at our table? A new analysis of the feed/food debate. Global Food Security. 14:1-8.
Naranjo, A., A. Johnson, H. Rossow and E. Kebreab. 2020. Greenhouse gas, water, and land footprint per unit of production of the California dairy industry over 50 years. J. Dairy Sci. 103:
Nesperti, S., S. Mandolesi, J. Buysse, T. Latvala, P. Nicholas, S. Padel, E.J. Van Loo and R. Zanoli. 2021. Consumer perceptions of sustainable practices in dairy production. Agricultural and Food Economics. 9:1-26.
Oltjen, J.W. and J.L. Beckett. 1996. Role of ruminant livestock in sustainable agricultural systems. J, Anim. Sci. 7:1406-1409.
Patel, M., U. Sonesson and A. Hessle. 2017. Upgrading plant amino acids through cattle to improve the nutritional value for humans: effects of different production systems. Animal. 11519-528.
Pimentel, D., and M. Pimentel. 2003. Sustainability of meat-based and plant-based diets and the environment. Am. J. Clin. Nutr. 78(suppl):660S-663S.
Rotz, C.A., M.E. Corson, D.S. Chianese, F. Montes, S.D. Hafner, H.F. Bonifacio, and C.U. Coiner. 2026. The Integrated Farm System Model (IFSM). Reference manual version 4.3. USDA Agricultural Research Service.
Schiano, A.N., W.S. Harwood, P.D. Gerard, and M. A. Drake. 2020. Consumer perception of the sustainability of dairy products and plant-based dairy alternatives. J. Dairy Sci. 103:11228-11243.
Segerkvist, K.A., H. Hansson, U. Sonesson and S. Gunnarsson. 2020. Research on environmental, economic, and social sustainability in dairy farming: A systematic mapping of current literature. Sustainability. 12:5502-5516.

Somerville, S., D.A. Sumner, J. Fadel, Z. Fu, J.D. Hart and J. Heguy. 2020. By-product use in California dairy feed has vital sustainability implications. ARE Update 24(2):5-8. University of California Giannini Foundation of Agricultural Economics, Environmental Science and Pollution.

Tricarico, J.M. 2016. Role of dairy cattle in converting feed to food. Proc. Tri-State Nutr. Conf. Fort Wayne, IN. pp:49-57.

Van Amburgh, M.E., K.L. Russomanno, R.A. Higgs and L.E. Chase. 2019. Invited review: Modifications to the Cornell Net Carbohydrate and Protein System related to environmental issues- Capability to evaluate nitrogen and phosphorus excretion and enteric carbon dioxide and methane emissions at the animal level. Appl. Anim. Sci. 35:101-113.

Van Soest, P.J. 1982. Nutritional ecology of the ruminant. O&B Books, Inc. Corvallis, OR.

Veltman, K., C.A. Rotz, L. Chase, J. Cooper, P. Ingraham, R.C. Izaurralde, C.D. Jones, R. Gaillard, R.A. Larson, M. Ruark, W. Salas, G. Thoma and O. Jolliet. 2018. A quantitative assessment of Beneficial Management Practices to reduce carbon and reactive nitrogen footprints and phosphorus losses on dairy farms in the US Great Lakes region. Agric. Systems. 166:10-25.

Von Keyserlingk, M.A.G., N.P. Martin, E. Kebreab, K.F. Knowlton, RJ. Grant, M. Stephenson, C.J. Sniffen, J.P. Harner, A.D. Wright, and S.I. Smith. 2013. Invited review: Sustainability of the US dairy industry. J. Dairy Sci. 96:5405-5425.

Waller, J.C. 2020. Byproducts and unusual feeds. In: Feedstuffs reference issue and nutrition guide. Feedstuffs. St. Charles, IL. Pp:12-18.

Weimer, P.J. 1996. Why don't ruminal bacteria digest cellulose faster? J. Dairy Sci. 79:1496-1502.

Widmar, N.O., C.J. Morgan, C.A. Wolf, E.A. Yeager, S.R. Dominick, and C.C. Croney. 2017. US resident perceptions of dairy cattle management practices. Agricultural Sciences. 8:645-656.

Wilkinson, J.M. 2011 Re-defining efficiency of feed use by livestock. Animal. 5:1014-1022.

Wilkinson, J.M. and M.R.F. Lee. 2018. Review: Use of human-edible animal feeds by ruminant livestock. Animal. 12:135-1743.