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Economic Analysis of High-Oleic Soybeans in Dairy Rations

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ABSTRACT

We evaluate the potential economic impact of using high-oleic soybeans (HOS) in dairy rations based on a synthesis of results from 5 prior feeding trials. Milk Income Less Feed Costs (MILFC) per cow per day is calculated based on assumed increases in milkfat production and increased cost of rations including HOS. Impacts of changes in MILFC are evaluated for herds with different numbers of milking cows, and the total volume of HOS required to support different proportions of US dairy cows is calculated. A dynamic supply chain model assesses the potential market impacts of increases in butterfat supply. The increase in milkfat from the substitution of 5% of ration dry matter with whole HOS (1.4 kg cow^{-1} day^{-1}) has the potential to increase MILFC by up to \$0.27 cow^{-1} day^{-1}, or an increase the average value of milk by \$0.29/45.4 kg for a cow producing 41 kg /day. Changes in MILFC are highly correlated with the price of butter but were positive for butter prices observed from January 2014 to September 2020. HOS impacts on MILFC suggest the potential for increases in farm profitability of \$33,000 per year for a dairy feeding 500 milking cows. Scaled-up use of HOS by US dairy farmers would increase butterfat supplies and lower the butterfat price to a small extent, but these aggregated effects do not offset the positive impacts of MILFC at the farm level.
Key words: high-oleic soybeans, dairy rations, economics

INTRODUCTION

Feed costs are a major expense on most US dairy farms (USDA, 2022) motivating the evaluation of rations to improve the production of milk components at reduced costs. Previous studies (Lopes et al., 2017; Weld and Armentano, 2018; Bomberger et al., 2019) have indicated that the use of high-oleic soybean (HOS) in various forms can have benefits as a component of dairy rations, but the economic implications of HOS use have not been previously evaluated. Five experiments available from the literature (Lopes et al., 2017; Weld and Armentano. 2018) and recent presentations (Bomberger et al., 2019; Khonkhaeng et al., 2020) investigated the effect of high oleic soybean products on milk production in dairy cows (details in Table 1). All previous studies with HOS treatments used Plenish® soybeans. These experiments utilized diverse designs and investigated expeller soybean meal, raw ground and whole soybeans, and roasted cracked soybeans. The limited number of studies and differences in products and feeding levels preclude conducting a full statistical meta-analysis. However, a simple quantitative summary of the data shows little to no effect on feed DMI or milk yield. There also is no clear effect on milk protein concentration and yield and differences observed in individual experiments likely was due to specific processing of each treatment. High oleic soybeans did demonstrate a consistent ability to increase milk fat yield. These 5 studies indicate that high oleic soybeans increased milk fat yield 65 g/d on average compared with a control soybean with equivalent dietary fat. This increase is mechanistically supported by oleic acid being a lower risk for biohydrogenation-induced milk fat depression (He et al., 2012).

The experimental evidence on feeding HOS as a part of dairy rations in various forms has the potential to increase milkfat content while maintaining milk yields and the production of other components of value (protein, lactose). An increase in milkfat production will add value to milk under the component-based pricing system that links the price paid to producers to the components produced. To achieve increased milkfat production, the ration fed would include various forms of HOS substituting for other ingredients, which can result in an increase in feed costs. An increase in milk value larger than an increase in feed costs suggests that

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the feeding of HOS could increase net returns per cow and per farm.

This study seeks to complement existing information by evaluating the economic incentives for HOS use in dairy rations and quantifying the potential use by US dairy farms. Our specific objectives are a) to evaluate the impact of the use of HOS in dairy rations on milk income less feed costs (MILFC) per cow and per farm, b) to estimate the potential volume of HOS that would be required for increasedHOS use and c) to discuss the potential market implications for dairy resulting from increased use of HOS in dairy rations.

MATERIALS AND METHODS

We assessed the impact of HOS on MILFC per cow per day (Equation 1) considering both the change in the value of milkfat produced (Equation 2) less changes in the feed costs for rations incorporating HOS (Equation 3).

Change in MILFC = Change in Value of Fat Produced Per Cow Per Day – Change in Feed Costs Per Cow Per Day (1)

where

Table 1: Summary of production responses to high oleic treatments

Experiment Treatments			Milk composition				
P-values	DMI, kg/d	Milk, kg/d	Fat, %	Fat, kg	*t*10C18:1, % FA	Protein, %	Protein, kg
Lopes 2017 (Conv. expeller compared with HO expeller and HO roasted soybeans)[1]							
Conv. Expeller	27.1	42.7	3.55	1.53	0.48	2.73	1.16
HO Expeller	27.8	42.0	3.74	1.60	0.42	2.72	1.15
HO RWSB	27.8	41.8	3.76	1.60	0.40	2.78	1.17
P (C vs HO Exp)	NS	NS	<0.01	NS	<0.01	NS	NS
P (C vs RWSB)	NS	NS	<0.01	NS	<0.01	0.09	NS
Weld 2018 Exp1 (Conv. vs HO whole soybeans on an equal fat basis in primiparous and multiparous cows)[2]							
Conv. WSB (Prim)	22.7	40.5	4.13	1.65	0.30	2.97	1.19
HO WSB (Prim)	23.5	38.4	4.08	1.58	0.23	3.03	1.18
Conv WSB (Mult)	26.5	45.1	3.84	1.70	0.38	3.05	1.36
HO WSB (Mult)	26.8	45.0	4.07	1.84	0.3	3.06	1.40
P (Conv vs HO)	NS	NS	NS	NS	NS	NS	NS
Weld 2018 Exp2 (Low fat control, Conv and HO soybeans either as ground or whole)[3]							
Low Fat	26.5	48.0	3.25	1.54	1.08	3.18	1.51
Conv. Grd SB	26.3	48.8	3.09	1.49	3.08	3.09	1.5
HO Grd SB	26.3	47.2	3.5	1.64	1.6	3.18	1.49
Conv. WSB	26.7	48.5	3.4	1.64	2.06	3.08	1.49
HO WSB	26.6	46.8	3.53	1.63	0.97	3.13	1.4
P (HO)	NS	<0.01	NS	NS	<0.01	0.01	NS
P (HO Grd)	NS	NS	<0.01	0.01	NS	NS	NS
P (HO WSB)	NS	NS	NS	NS	NS	NS	NS
Bomberger unpublished (Conventional vs HO roasted soybeans at 5 and 10%)[4]							
5% Conv. RSB	27.5	43.8	3.28	1.39	0.79	3.04	1.29
5% HO RSB	27.9	43.4	3.42	1.46	0.62	3.06	1.31
10% Conv RSB	28.9	43.7	3.46	1.46	0.89	3.05	1.32
10% HO RSB	29.4	44.8	3.66	1.57	0.63	3.08	1.33
P (Conv v HO)	NS	NS	<0.05	0.08	0.01	NS	NS
P (Level)	<0.001	NS	0.01	0.01	NS	NS	NS
Khonkhaeng unpublished (Increasing HO roasted soybean substituted for solvent and heat treated SBM)[5]							
0% HO RSB	21.4	40.6	4.02	1.62	0.43	3.04	1.21
5% HO RSB	21.4	40.8	4.02	1.63	0.44	2.94	1.19
10% HO RSB	21.5	41.5	4.06	1.67	0.45	2.94	1.21
15% HO RSB	21.3	41.3	4.16	1.71	0.46	2.92	1.19
P (Linear HO)	NS	NS	NS	NS	0.06	0.02	NS

[1]Lopes et al. (2017) compared diets that contained 17% extruded conventional or high oleic SBM or 7.4% roasted high oleic soybeans fed for 28 d in a Latin square design.

[2]Weld and Armentano (2018) in their first experiment fed 28 first lactation (primiparous) and 35 multiparous cows conventional or high oleic raw whole soybeans (WSB) to provide 2.8% EE in the diet (15.9 and 19.1% of DM).

[3]Weld and Armentano (2018) in their second experiment used 10 first lactation and 10 multiparous cows in a Latin square design with 14 d periods. Treatments were a low fat control, raw conventional and HO soybeans either ground (Grd) or fed whole (WSB). Soybeans increased dietary fat ~3.4 percentage units.

[4]Bomberger et al. (2019) fed 18 multiparous cows in a crossover design either conventional to HO roasted soybeans (RSB) at 5% of the diet for 14 d and 10% of the diet for 10 d.

[5]Khonkhaeng et al. (2020) 8 first lactation and 8 multiparous cows in a Latin square design were 0, 5, 10, and 15% HO roasted soybeans (RSB).

Change in Value of Fat Produced Per Cow Per Day = Change in Milkfat Production (g cow^{-1} day^{-1}) x Butterfat value ($/g) (2)

and

Change in Feed Costs Per Cow Per Day = Change in Costs for HOS ($ cow^{-1} day^{-1}) + Change in Costs for Increased DMI to Maintain Energy Balance ($$cow^{-1}$ day^{-1}) (3)

An increase in MILFC implies economic incentives for HOS use in dairy rations, and the unit of measure ($ cow^{-1} day^{-1}) aligns with common metrics used to assess dairy rations.

Given the biological response of increased fat production, accounting for changes in the value of butter is key to an economic assessment of the use of HOS in dairy rations. Most US milk is priced under Federal Milk Marketing Orders, where a system of *classified pricing* assigns a value to butterfat in farm milk based on market prices of butter. The butterfat value is determined by the formula (Wholesale Butter Price – Make Allowance for Butter)/Butter Yield. The Make Allowance reflects costs of processing milk into butter and Butter Yield reflects the amount of butterfat required to produce butter. US butter is typically 80% fat with the remainder a small amount of other dairy solids and water. The butterfat value in $/kg is calculated each month for butterfat and is similar across different uses of milk (for example, beverage milk, cheese or butter production). The price of butter and the butterfat value can vary considerably over time. During the period from January 2014 to December 2020, for example, the price of butter ranged from $0.57/kg to $1.29/kg, or from 40% below the average butter price during that time to 36% above the average. Because the increase in milk value depends on the butterfat price, assessing the economic impacts of feeding HOS requires consideration of the range of observed butter prices.

An evaluation of the change in MILFC with feeding HOS could consider many factors, including the increased yield of milkfat, various forms of the HOS (whole, ground, roasted) and many different substitutions for other products in the ration. Ideally, milkfat production for different rations would be compared with the cost of a ration that is often formulated with the assistance of nutrition software programs that ensure nutrient requirements are met and assess ration costs. The current evidence from 5 experimental trials (Table 1) is not sufficiently robust to permit this more comprehensive type of assessment at present. Thus, we undertook a simpler evaluation as a first approximation to the incentives for the inclusion of HOS. Based on information from the available experimental trials that fed HOS and other studies that examined the impact of changing the proportion of C18:2 to C18:1 fatty acids in the ration based on Dorea and Armentano (2017), the base analysis assumed an increase of 50g milkfat production per cow per day. This increase was assumed to be achieved by substituting whole raw HOS into the ration in place of whole raw conventional soybeans for 5% of ration dry matter, or 1.4 kg cow^{-1} day^{-1}, which maintains equal total dietary fat.

The change in ration cost required to achieve this increase is comprised of 2 components: the additional cost of HOS and the cost of additional dry matter intake (DMI) to maintain energy balance given increased fat synthesis (production). We assumed that the additional cost of HOS compared with conventional soybean was a price premium of $0.018/kg ($0.50/bu) based on approximate premiums for HOS used incentive programs in 2020 offered by oilseed processors interested in HOS oil for food processors (John Jansen, personal communication). Premiums for HOS have fluctuated since that time to a value as high as $0.055/kg ($1.50/bu) but have since decreased. This assumes that the HOS would be sourced externally to the farm and does not directly include any additional transportation or logistics costs incurred between the seller and the purchasing dairy. We assumed there were no differences in processing costs between conventional soybeans and HOS. We assessed the impact of the assumed size of the premium paid for HOS by evaluating a higher value of ($0.055/kg) for HOS and compared the distribution of MILFC values to that for the assumed value of $0.018/kg.

The amount of additional DMI required to maintain energy balance with an increase of 50g of milkfat production was about 0.3 kg cow^{-1} day^{-1} based on the additional energy required using a value of 1.65 Mcal NE_L / kg DM. We assigned a cost for the increased DMI based on the national average ration value reported for the purposes of the Dairy Margin Coverage program and its predecessor the Margin Protection Program-Dairy, which provides a monthly value for a national weighted average ration for a US dairy cow (USDA Farm Services Agency, 2023).

Because the increase in milkfat can vary, we also evaluated the impacts of smaller milkfat increases of 40g cow^{-1} day^{-1} and 45g cow^{-1} day^{-1} and the breakeven milkfat increase. We assessed the impact of changes in butterfat values and feed costs from January 2014 to September 2020, a period that encompasses a good deal of variation in both butter prices and feed costs. We further explored the relationship between increases in MILFC due to HOS in rations and butter prices with a simple linear regression model. This model regressed the increase in MILFC on the butter value and the ration value in addition to a constant.

In addition to the impact per cow per day, it is relevant to compute the impact at the farm level, assuming only the increased value of MILFC. This provides a point of comparison for subsequent analyses of the costs that might be incurred for on-farm production and processing of HOS by dairy farmers or their feed-producing partners. Based on the assessments of the dairy nutritionists, it would be possible to feed a ration with whole raw HOS to all cows in the milking herd, but we report the values based on milking cows fed HOS (which may not include all milking cows in the herd). To calculate potential returns per farm, we multiply the changes in MILFC per cow times the number of milking cows.

The volume of HOS that would be required for dairy rations was evaluated based on assumptions about the proportion of US cows fed HOS in some form. For this assessment, we assumed a conservative 1.4 kg of whole HOS fed per cow per day, although there is evidence that some US dairy producers already using HOS in their feed up to 3 times that much.

Adoption of HOS to feed a substantial number of cows could affect the supply-demand balance for dairy components in the marketplace. An increase the average amount of fat in milk would also affect the yields of cream and skim milk given the separation processes that are the typical first steps in dairy processing. If the number of cows fed HOS is sufficiently large, we would expect that the increased butterfat supply would have a decreasing effect on butter prices, a decrease that would also be reflected in farm milk prices. It is not uncommon for the adoption of an agricultural production technology to have this sort of offsetting effect on profitability (e.g., Simões et al., 2019). A key question is whether this effect would be large enough in this case to offset the farm-level benefits of feeding HOS or lower overall farm profitability.

We assessed these questions with the Dynamic Global Dairy Supply Chain model (Nicholson and Stephenson, 2015). This model represents the supply, processing, transportation and consumption of milk and dairy products monthly for 15 global regions. It can be used to assess the impacts of market developments and policy instruments on profitability of 8 US dairy farm types. We modified model assumptions to account for increased fat content of milk and the associated increases in milk value and feed costs. We evaluated the impacts of a range of adoption, up to 25% of US cows fed HOS during the time period January 2014 to December 2020.

RESULTS AND DISCUSSION

The change in MILFC was positive for all values of increased milkfat production during all months analyzed (Table 2). The mean impact was highest for the largest assumed increase in butterfat (50g butterfat cow^{-1} day^{-1}), ranging from \$0.07 cow^{-1} day^{-1} to \$0.27 cow^{-1} day^{-1}. These values are large enough to generate interest on the part of dairy farmers, corresponding to increases in average milk price of about \$0.29/45.4 kg (100 lbs) for a cow producing 41 kg/day. We also evaluated the amount of increased butterfat necessary to break even, that is, for which the mean change in MILFC value with HOS feeding was zero. This break-even value was about 15g butterfat cow^{-1} day^{-1}, which resulted in a range of differences for the monthly values from -\$-0.025 cow^{-1} day^{-1} to \$0.038 cow^{-1} day^{-1} during the period analyzed.

Not surprisingly, changes in MILFC to feeding HOS in dairy rations are highly correlated with the price of butter. When butter prices are high, the increase in MILFC with HOS is larger (Figure 2). Variation in butter prices explains about 95% of the variation in the values of increased MILFC achieved feeding HOS.

The impact on MILFC of changes in butterfat price, HOS premium and ration cost can be calculated using elements of equations (2) and (3). We find that an increase in the premium for HOS of \$0.01/kg would decrease the MILFC by 1.4 cents cow^{-1} day^{-1}, an increase in the butterfat price of \$0.10/kg would increase MILFC by 0.5 cents cow^{-1} day^{-1}, and an increase in the ration value of \$0.01/kg would decrease the MILFC by 0.3 cents cow^{-1} day^{-1}.

The average value of the increase in MILFC or its distribution were not markedly different with assumed premium values of \$0.018/kg and \$0.055/kg (Figure 3) The average value of the increase in MILFC decreased by about \$0.05 cow^{-1} day^{-1} with the higher assumed value of HOS premium, but the minimum value was still positive. In practice, the premium that might be paid for HOS in dairy rations would be driven by the milkfat production response, the price of alternative ration ingredients and the value of butterfat.

Because the mean value of the increase in MILFC is positive, it is not surprising that there is an increase in farm income as a result. Our analysis does not account for other potential effects of herd size, which might include economies of scale in feed purchasing or different rations by cow group. The farm-level value is provided to provide perspective and context by farm size, given that the absolute magnitude of financial benefits from HOS feeding will differ even if the per-cow values are the same. The farm-level financial impact from a change in feeding practices could affect the interest in adopting

Table 2. Characteristics of Impact on Milk Income Less Feed Costs (\$ cow^{-1} day^{-1}) of Substitution of 5% High-Oleic Soybeans for Conventional Soybeans in Dairy Cow Rations for Different Assumptions About the Impact on Milkfat Yield

	Fat increase from high-oleic soybeans:		
Metric	40g cow^{-1} day^{-1}	45g cow^{-1} day^{-1}	50g cow^{-1} day^{-1}
Mean impact	0.1379	0.1583	0.1787
Minimum impact	0.0490	0.0583	0.0676
Maximum impact	0.2133	0.2432	0.2730
Standard Deviation	0.0340	0.0382	0.0425
Coefficient of Variation	0.2464	0.2414	0.2376

NOTE: All values are in \$ cow^{-1} day^{-1}, based on assumed response to replacement of 5% of DMI with whole HOS, 1.4 kg HOS cow^{-1} day^{-1}. Minimum and Maximum impacts are estimated based on variation butterfat value and feed costs using monthly data from January 2014 to September 2020.

a practice such as HOS feeding. For a farm with 2,000 cows, the increase in farm income from feeding HOS as we have assumed is more than \$130,000 per year based on the mean values of MILFC during 2014 to 2020 (Table 3). During periods of high butterfat price, this increase in farm income would be larger. The amount of soybeans required for the farm and the acres that would need to be planted also increase linearly with the number of cows, but provide a benchmark for the amount of farm storage and changes to the cropping pattern that would be required for own production.

The previous economic analysis and discussion of practical considerations suggest that there would be economic incentives for HOS use in dairy rations and considerable interest in exploring their use among dairy producers. With currently available information, it is difficult to estimate the potential US market size for HOS and how it might evolve over time given the multiple factors that will influence it. Factors favoring

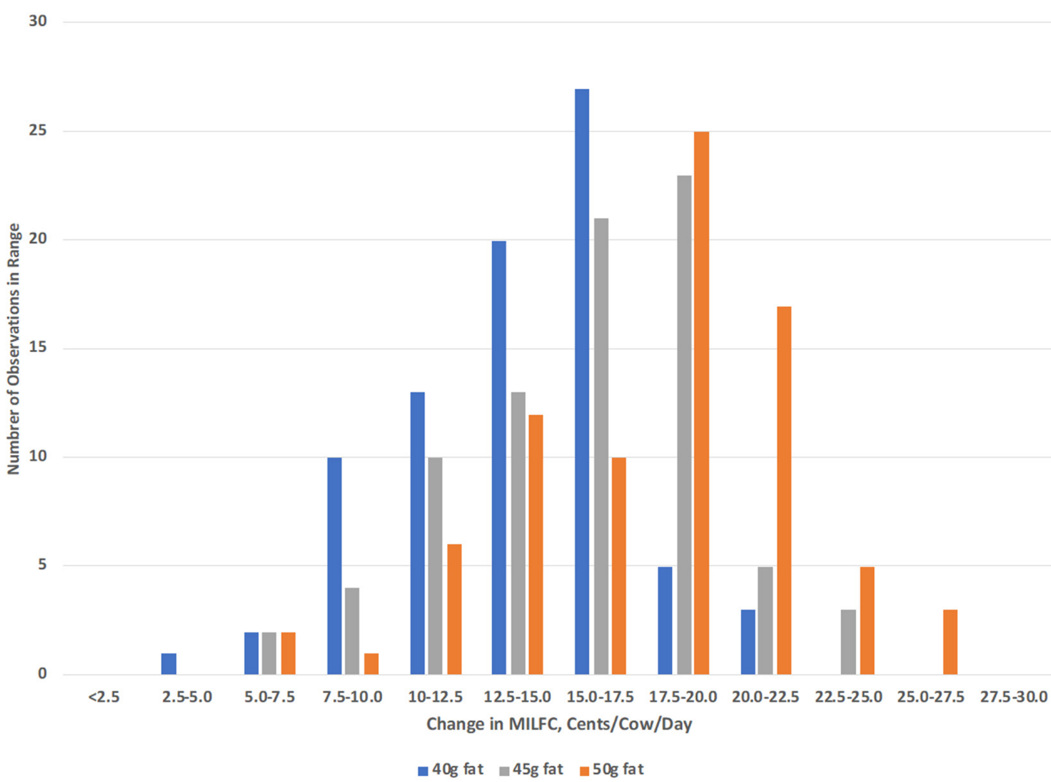

Figure 1. Distribution of Values of Differences in Milk Income Less Feed Cost with Substitution of 5% High-Oleic Soybeans, January 2014 to September 2020, Assumed Fat Increase of 40 g cow^{-1} day^{-1}, 45g cow^{-1} day^{-1} and 50 g cow^{-1} day^{-1}

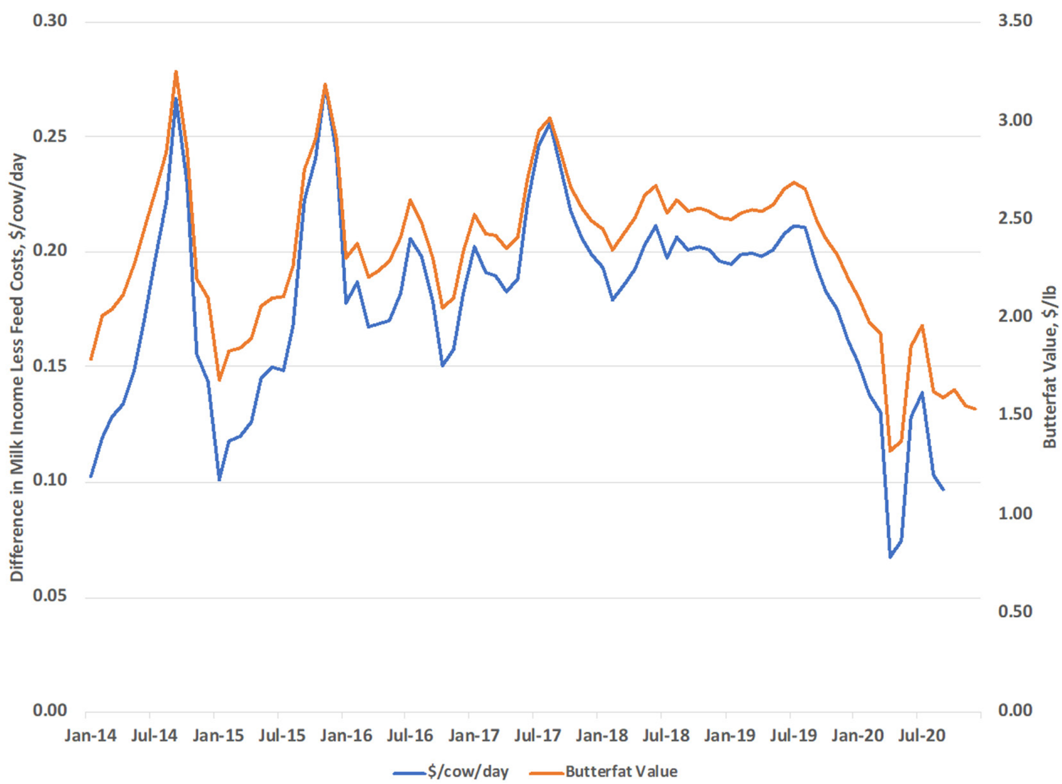

Figure 2. Differences in Milk Income Less Feed Cost with Substitution of 5% High-Oleic Soybeans, January 2014 to September 2020, Assumed Fat Increase of 50 g cow^{-1} day^{-1}, and Butterfat Value

HOS use include an increased awareness of the role of fats in dairy rations and the costs of HOS relative to supplemental fats. There is also increasing interest on the part of dairy farmers in controlling more of their own feed 'supply chain', so availability of HOS seed suited to traditional dairy areas and for farms with a land base and cropping program will also promote producer interest in HOS. Access to sufficient quantities of HO soybeans in various processed forms, such as roasted, ground or cracked, will be important for farms with less focus on cropping operations, as will the cost and availability of alternative ration elements such as dried distillers' grains (DDG) from the ethanol industry. Many of these factors have a spatial dimension that is not fully explored in this assessment.

Given the multiple factors affecting potential use in dairy rations, expected total volumes are calculated based on alternative assumptions about the proportion of US dairy cows fed HOS in some form (Table 4). For this assessment, we assumed a conservative 1.4 kg of whole HOS fed per cow per day, although there is evidence that some dairy producers already using HOS in their feed up to 3 times that much (A. Lock; Michigan State University, East Lansing, Michigan, personal communication). Even at lower levels of uptake (10% or 20%), the use of HOS in dairy rations would imply a considerable increase in HOS acres planted given the seed availability of 550,000 acres in 2021 and 900,000 in 2022 (J. Jansen, United Soybean Board, Chesterfield, Missouri, personal communication).

The supply chain modeling analysis indicated that feeding of HOS to 25% of the US milking dairy cows would have reduced average butter prices by \$0.014/kg and milk prices by \$0.03 per 45.4 kg (100 lbs, 1 hundredweight) during the period analyzed (Table 5). Differences in prices with HOS were smaller during the first 2 years but became larger as farms expanded production due to increased profitability. These reductions in milk price are not sufficiently large to undermine the incentives for use of HOS at the farm level and did not markedly affect model calculations of Net Farm Operating Income (NFOI), one measure of farm profitability. Moreover, dairy processors, exporters and dairy product consumers benefitted from the increased sales and lower prices of dairy products that resulted from the milk supply response to increased profitability.

Although there are practical considerations (including HOS availability) that will affect future use, our analysis suggests that incorporation of HOS in dairy rations can have positive impacts on MILFC and has

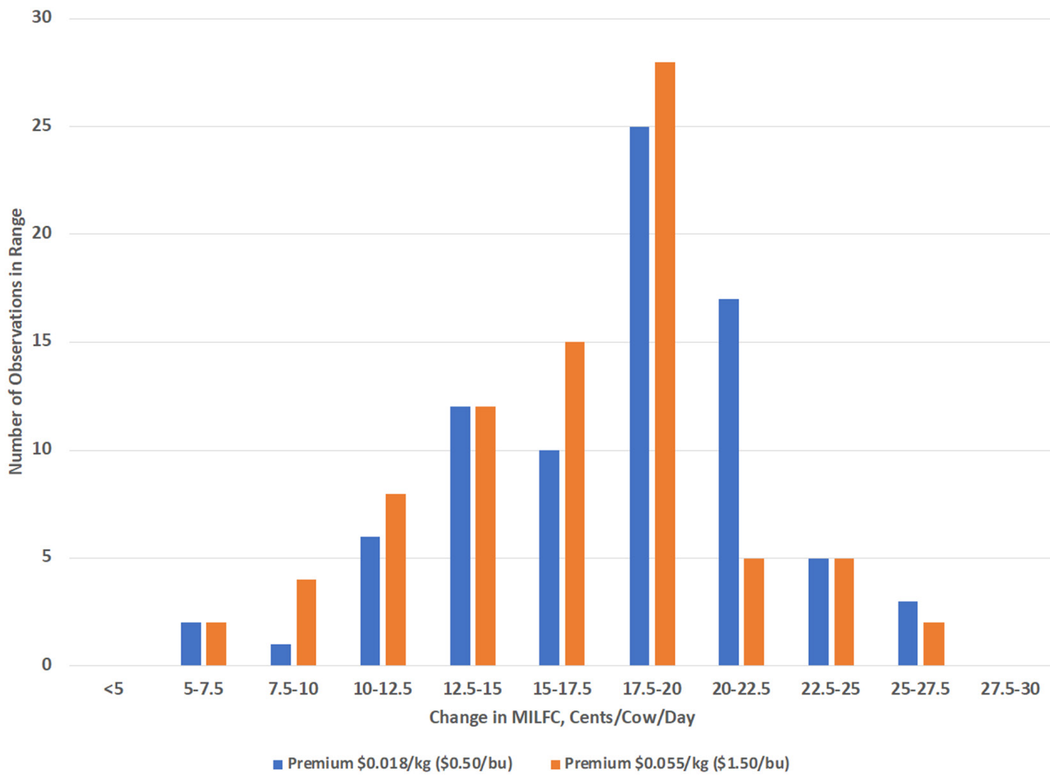

Figure 3. Distribution of Values of Differences in Milk Income Less Feed Cost with Substitution of 5% High-Oleic Soybeans, January 2014 to September 2020, Assumed Fat Increase of 50 g / cow /day and HOS Premiums of $0.018/kg ($0.50/bu) and $0.055/kg ($0.1.50/bu).

the potential to increase dairy farm incomes. However, there is a need for additional information for a more comprehensive assessment. First, many previous studies of HOS have focused on documenting the effects of alternative forms of fat in the diet and testing hypothesis regarding the underlying biochemical mechanisms. Additional feeding trials with a wider variety of feed ingredients commonly used on dairy farms and preferred forms of HOS would be relevant and provide an enhanced basis for economic analysis. This might usefully include on-farm and demonstration trials, if carefully conducted and monitored. Second, our farm-level economic analysis is relatively simplistic and indicative because it assumes a given (average) effect on milkfat cow^{-1} day^{-1} based on aggregated effects from the feeding trials. We assume no impact on milk yields, % protein, % lactose, nor impact on reproductive performance or cow longevity. As noted above, additional information about these potential effects would allow improved estimates of the incentives for use at the farm level.

Our economic analysis also assumes a specific substitution of HO whole beans for conventional whole beans because of the limitations of the existing experimental

Table 3. Potential Farm-Level Financial Impacts of Substitution of 5% High-Oleic Soybeans for Conventional Soybeans in Dairy Cow Rations and High-Oleic Soybean Use for Different Numbers of Milking Cows

Number of Milking Cows fed HOS	Increase in milk income less feed costs, $/farm/year	HOS Use, 1000 kg/farm/year	HOS Area Required, ha/farm
100	6,523	51	17
500	32,616	254	84
1,000	65,232	508	168
2,000	130,465	1,015	335
10,000	652,323	5,073	1,677

NOTE: Values shown assume response of 50g milkfat cow^{-1} day^{-1} in response to the substitution of HOS for conventional soybeans. Assumes all cows fed HOS and a HOS Soybean yield of 3026kg/ha (45 bu/acre). Assumes the mean value of MILFC of $0.18 cow^{-1} day^{-1} multiplied by the number of cows fed HOS times 365 d.

Table 4. Potential Impact on Quantities of High-Oleic Soybeans, Land Required and Farmer Premiums based on Assumed Values of the Proportion of US Cows Fed High-Oleic Soybeans

Proportion of US Cows fed HOS	Quantity of HOS used in dairy rations, mil kg/yr	Quantity of HOS used in dairy rations, mil kg/yr	Land Area of HOS required, 000 ha	HOS area as a % of total US soybean area	Value of high-oleic premiums paid for farmers, $ mil/yr
10%	474	463	157	0.5%	8.7
20%	947	953	313	0.9%	17.4
30%	1,421	1,415	469	1.4%	26.1
40%	1,894	1,905	626	1.9%	34.8
50%	2,368	2,368	783	2.3%	43.5
60%	2,842	2,830	939	2.8%	52.2
70%	3,315	3,320	1,096	3.3%	60.9
80%	3,789	3,783	1,252	3.8%	69.6
90%	4,262	4,273	1,408	4.2%	78.3
100%	4,736	4,736	1,565	4.7%	87.0

NOTE: Quantity calculations assume 1.4 kg HOS cow^{-1} day^{-1}, a population of 9.335 million dairy cows, 27.2 kg / bu, and HOS soybean yields of 3026 kg/ha (45 bu/acre). The percentage value for HOS based on 33.3 million ha (82.3 million acres) harvested in 2020. The value of HOS premiums paid to farmers is calculated based on a premium of $0.018/kg ($0.50 / bu) and assumed purchase rather than own production. The shaded percentage rows seem unlikely but are shown for the purposes of comparison.

evidence. This does not reflect the greater complexity and opportunities for ration modifications given the ingredients currently fed (such as fat supplements or DDG). With a wider range of possible substitutions, it is conceivable that feed costs could be decreased with the use of HOS, rather than increased as assumed here. In particular, substituting HOS for currently fed fat supplements may have the potential to lower costs. Many nutritionists balance diets to a maximal level of linolenic acid (18:2) due to its high risk of induction of milk fat depression and this commonly limits the inclusion of dietary fat from byproducts and oilseeds. Alternate approaches to direct substitution for conventional soybeans may allow increased inclusion of economical, but high 18:2 byproducts, such as DGS, or increased inclusion of soybeans in partial substation for saturated FA supplements and calcium salts of FA. This may also allow increased inclusion of home-grown or locally-grown feeds. However, the increased inclusion of HO soybeans also could also affect the need for (and type of) storage and processing equipment and thus result in increased costs.

We also do not examine in depth how the mode of HOS sourcing affects economic incentives. We assumed that beans would be purchased rather than produced on farm, but farmers with a land base—especially those already growing soybeans in a crop rotation—could in principle 'source' HOS with little or no increased production costs. However, the relevant concept for economic analysis is that of opportunity costs—if the farm could produce and sell soybeans including the HOS premium, this should be reflected in the cost of using HOS in dairy rations, not the production cost. Additional consideration of regional differences in feed costs would complement this analysis given that national-average feed costs and ration values were used.

CONCLUSIONS

Our economic analyses are based on existing studies reporting the impact of feeding HOS on the production of milkfat. We find that under a wide range of butterfat market values and costs of dairy rations, increased milkfat production from HOS use has the potential to increase MILFC and positively affect dairy farm operating incomes. This result is unaffected when accounting for the market impacts (lower butterfat values) of additional butterfat production if HOS use in dairy

Table 5. Simulated Impacts of Alternative Levels of Feeding HOS on Butter and Farm Milk Prices during January 2014 to December 2020

Proportion of US Cows fed HOS soybeans	Impact on Average Butter Price Compared with Baseline with no HOS feeding, $/kg	Impact on Average Farm Milk Price Compared with Baseline with no HOS feeding, $/45.4 kg[a]
5%	−0.002	−0.005
10%	−0.005	−0.01
25%	−0.014	−0.03

Source: Analyses with Dynamic Global Dairy Supply Chain Model accounting for increases in milkfat, profitability and feed costs with HOS use in dairy rations.

[a]45.4 kg equals 100 pounds or 1 hundredweight (cwt). Milk in the US is priced in $/cwt.

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rations were scaled up to a substantive proportion of US dairy cows. Future work could better document the impacts of the use of different forms of HOS on milk yields and the production of other dairy components, as well as the practical dimensions of HOS availability and the mode of sourcing HOS by US dairy farms.

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