RESEARCH ARTICLE

Survey of California dairy nutritionists on extent of byproduct usage

Results from a survey of dairy cattle nutritionists show that byproducts are included in California dairy rations at an average rate of 40.9%.

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Abstract

Byproduct feedstuffs play a crucial role in California dairy rations and contribute to the sustainability of the industry, but the extent of their usage in the state has not been widely investigated. In March 2022, we sent a byproduct feeding and management survey via email to 61 dairy cattle nutritionists in California. Twenty-six completed surveys were included in the final data analysis (response rate = 46%; n = 26/61). Nutritionists reported servicing 498 dairy farms that represented approximately 936,700 milking cows. Respondents serviced mostly cows housed in San Joaquin Valley herds (87.6%), with some cows housed in Northern California (5.5%) and Southern California (6.9%) regions. Survey respondents also reported 58 byproducts that were fed on California dairies; almond hulls and whole cottonseed were the most frequently utilized byproducts. The average lactating ration byproduct inclusion rate was estimated at 40.9% on a dry matter (DM) basis. Looking ahead to the next five years, 20 nutritionists (80%) thought byproduct usage would increase in California dairy rations, with fewer anticipating decreased (n = 3; 12%) or unchanged (n = 2; 8%) usage.

California is the top milk producing state in the nation. Milk is California's number one ranked agricultural commodity, with $10.4 billion in sales in 2022 (CDFA 2024a). The California dairy industry's importance to the state's economy is demonstrated by indirect and induced effects valued at $57.7 billion and 179,900 California jobs in 2018 (Matthews and Sumner 2019). California also produces more than 400 commodities (CDFA 2022), generating a range of byproducts that serve as feed for dairy cattle. Byproduct feedstuffs, characterized as the portions of commodities without utility for human consumption, have become a key component of dairy rations in the state.

Previous studies described byproducts' chemical composition, variability and digestibility (DeGroot et al. 2007; DePeters et al. 2000), but the extent of byproduct usage in California rations has not been widely investigated, despite California's greater usage of byproducts as compared with other dairy regions (Naranjo et al. 2020). In California's San Joaquin Valley, 95% of dairies incorporate byproducts into their rations (Somerville et al. 2020).

Cull watermelon used as dairy feed. California produces a number of fresh commodities, a portion of which find their way into California dairy rations. *Photo*: J. M. Heguy.

Current and future water availability and regulations in California will likely increase the already important role byproducts play in dairy rations to support the sustainability of dairy farms. The Sustainable Groundwater Management Act, with a goal of mitigating overdraft, will reduce the amount of groundwater that can be utilized for agricultural production (California Department of Water Resources 2024). Decreased ground and surface water availability for growing forage crops in the San Joaquin Valley, where approximately 90% of California's milk is produced, may create the need for byproduct feedstuffs to partially replace homegrown forages such as corn silage. Other circumstances, including extreme weather in the Midwest and disruption of commodities and byproducts delivered by rail, may warrant replacement with California-derived byproduct feedstuffs.

Byproduct feeding not only reduces water usage in feed production by replacing feedstuffs grown specifically for feeding cattle with commodity waste products, but also mitigates environmental impacts by diverting disposals from landfills. Consequently, byproduct feeding contributes to the current and future sustainability efforts of the California dairy industry. The objectives of this survey were to identify fed byproducts, estimate the percentage of the California dairy ration composed of byproducts, and describe the utilization of byproduct feedstuffs in California.

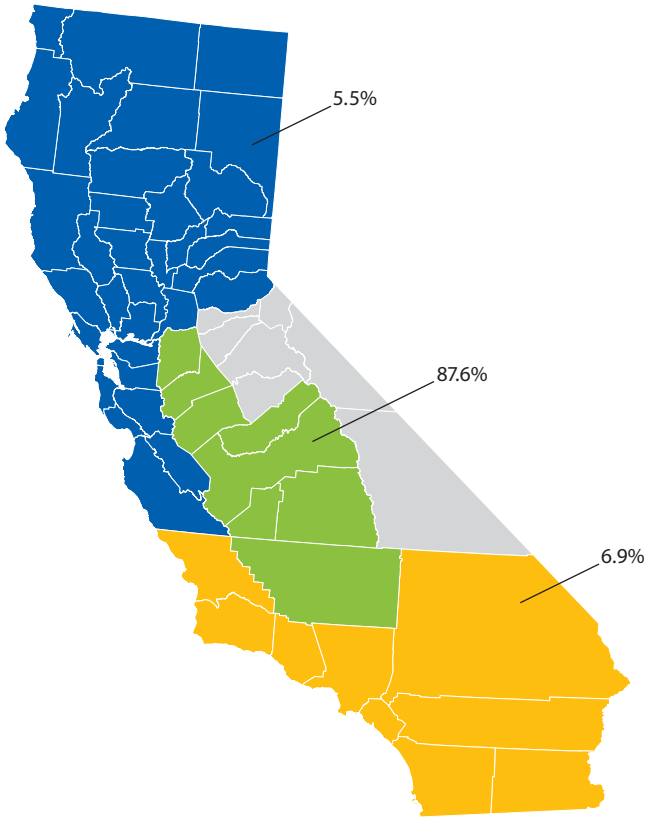

FIG. 1. Map of milking cow distribution in California. Blue, Northern California/Coast; green, San Joaquin Valley; yellow, Southern California.

Survey format, data analysis

We compiled a list of California dairy cattle nutritionists from allied industry contacts, University of California faculty, the California chapter of the American Registry of Professional Animal Scientists, and the authors' contact lists. In March 2022, we sent a byproduct feeding and management survey via email to nutritionists who practice in the state (n = 61). The email included an invitation letter to participate in the study and a link to the survey (Qualtrics, Provo, Utah). The objective of the study was clearly stated in the invitation letter. We provided a $50 value gift card to nutritionists who completed the survey. The study protocol was submitted to the Institutional Review Board (IRB) at the University of California Davis and was granted an exemption from IRB review (IRB ID: 1844800-1).

The electronic survey contained 23 questions that addressed (1) demographic information to determine applicability of the results, (2) byproduct utilization, (3) byproduct management, (4) byproduct feeding levels of lactating, dry and heifer rations, and (5) byproduct usage trends. The survey was designed to be completed in fewer than 10 minutes to promote survey participation and increase response rate. The first page of the questionnaire included a screening question to ensure that participants met the eligibility criterion, specifically that they were nutritionists formulating dairy cattle diets in California. There were 11 multiple choice (close-ended) and 13 fill-in-the-blank (open-ended) questions. The survey was tested by two independent nutritionists (not affiliated with a company or feed mill) prior to being sent to the larger group; this review did not result in changes to the orginal survey, and those responses were included in the final analysis.

Raw data were exported from Qualtrics (Provo, Utah) to an electronic spreadsheet using Microsoft Excel (Microsoft, Redmond, Wash.). Within each survey, we checked responses for typographical errors, logic, and completeness. Unanswered questions and questions with responses outside reasonable values were not included in the data analysis. When multiple values were provided for a single question (open-ended), the average was calculated and used. Descriptive statistics (measures of frequency, central tendency, and dispersion) were performed with R (version 4.0.4, Foundation for Statistical Computing, Vienna, Austria) using RStudio version 1.3.1073 (RStudio Inc., Boston, Mass.) with 'Rcmdr' package. All figures were created in Microsoft Excel.

Survey participants

Twenty-six completed surveys were included in the final data analysis (response rate = 46%; n = 26/61). Three incomplete surveys and two surveys from nutritionists without California clients were not included in the data summarization. This response rate was higher than the 12% obtained in a nationwide survey on crude

protein among dairy nutritionists (Prestegaard-Wilson et al. 2021). Most respondents were independent nutritionists (n = 24; 92.3%), while two worked for feed companies (7.7%). Nutritionists reported servicing 498 dairy farms that represented approximately 936,700 milking cows (n = 25); one nutritionist reported servicing 30 dairies but did not provide the number of cows serviced. Information on the number of dry cows and heifers serviced was not collected.

Survey data described 44.5% of California dairies (498 out of 1,117; USDA NASS 2022b), making it a comprehensive assessment of byproduct usage in California dairy rations. The number of dairies serviced by individual nutritionist ranged from two to 100 dairies, while the range of cows serviced ranged from 400 to 200,000 cows (median = 25,000). Cows were mostly housed in the San Joaquin Valley (87.6%), with some cows housed in Northern California (5.5%) and Southern California (6.9%) regions (fig. 1). In 2022, the San Joaquin Valley housed 87% of the state's 1.72 million milking cows (USDA NASS 2022a), demonstrating the importance of the eight county area, especially as it relates to byproduct consumption. Average milk yield of serviced herds, as reported by nutritionists, was 37.3, 28.6 and 33.6 kg/day for Holstein, Jersey and "other breed" herds, respectively.

Byproduct utilization

Survey respondents reported fifty-eight byproducts that were used on California dairies, some with definitions provided by the California Code of Regulations for Commercial Feed (CDFA 2024b). This question was "select all that apply," with the ability to write in additional entries. The most frequently reported byproducts utilized in California dairy rations are listed in table 1,

TABLE 1. Common byproducts utilized in California rations

Byproduct	Number of nutritionists utilizing (n = 26)
Almond hulls	25
Cottonseed, whole	25
Canola pellets	24
Soybean meal	24
Distiller's grains, dry	23
Almond hulls & shells	22
Canola meal	22
Straw, wheat	22
Wheat midds/millrun	21
Corn gluten feed	20
Molasses	20
Distiller's grains, wet	19
Soy hulls	19
Bakery waste	18
Grape pomace	18
Whey, liquid	18
Beet pulp	17
Whey, condensed	17
Fat (inert, animal, vegetable, liquid)	16
Citrus pulp	15
Citrus, cull	14
Cottonseed, pima	14
Poultry litter	14
Almond shells	13
Onions, cull	13
Straw, rice	13
Pomegranates, cull	12
Cottonseed meal	11
Garlic	11
Grain screenings	11
Straw, other*	11
Rice bran	10
Tomato pomace	10
Brewer's grains, wet	9
Safflower meal	9
Raisin tailings	8
Tomatoes, cull	8
Chaff hay	7
Olive pomace	7
Walnut meal	7
Brewer's grains, dry	6
Corn germ	6
Sunflower meal	6
Asparagus	5
Bloodmeal	5
Brewer's malt	5
Brewer's yeast, wet	5
Apples, cull	4
Apple pomace	4
Cherries, cull	4
Okara (soy pulp)	4
Sweet potatoes/yams, cull	3
Cabbage	2
Melons, cull	2
Kiwis, cull	1
Brocolli	1
Bell peppers	1
Almond meal (meats)	1

* Bermuda straw: n = 3; bean straw: n = 1; oat straw: n = 1; not specified: n = 6.

Decreased ground and surface water availability for growing forage crops in the San Joaquin Valley, where approximately 90% of California's milk is produced, may create the need for byproduct feedstuffs to partially replace homegrown forages such as corn silage.

with almond hulls and whole cottonseed utilized by 25 of the 26 nutritionists.

The main reasons for inclusion of byproducts into rations were value (worth the price, 30.8%), value and availability (30.8%), value and price (affordable, 3.8%), or the combination of availability, price and value (34.6%). Nutritionists utilized byproducts to replace forages (n = 25/26; 96.1%) or concentrates (n = 24/25; 96.0%) in formulated rations. In an open-ended question, almond hulls (88.5% of responding nutritionists) were the most frequently used byproduct as a forage replacement in lactating cow rations, followed by straw (30.8%) and citrus byproducts (23.1%; citrus byproducts = citrus and citrus peel) (fig. 2). Citrus byproducts (30.8%), whey (26.9%) and mill run (23.1%) were the byproducts most frequently reported as concentrate replacements.

A 2012 survey of 104 total mixed-rations fed on California dairy farms (Castillo et al. 2012) found that almond hulls were fed to lactating dairy cows at an average of 3.2 pounds per cow daily. A more recent survey found an increase in almond hull utilization at 5 pounds per cow daily (Heguy et al. 2022). California produces nearly 80% of the world's almonds (Almond Board of California 2023). In 2024, California produced 2.73 billion pounds of almonds, resulting in ample supply of almond hulls (USDA 2025). Almond hulls

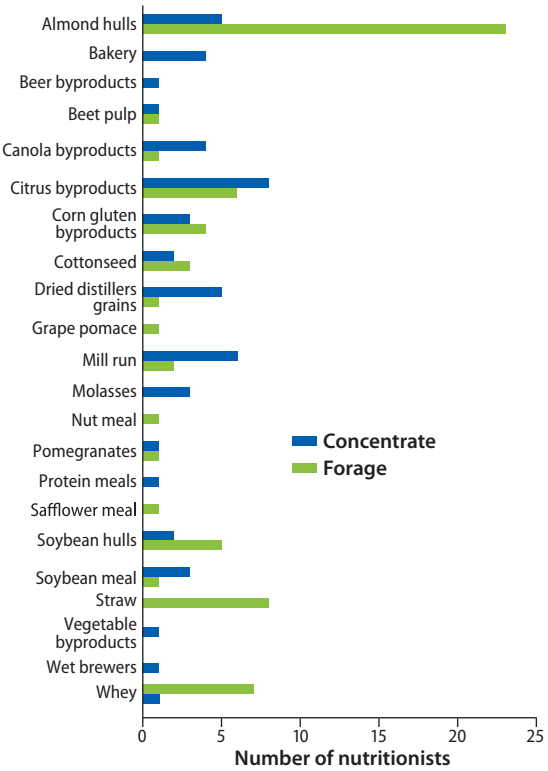

FIG. 2. Byproducts reported by number of nutritionists as replacements for concentrates (blue bar) and forages (green bar) in lactating cow rations. Citrus byproducts include citrus and citrus peel; corn gluten byproducts include corn gluten, corn gluten feed, gluten pellets and gluten; and straw includes straw and wheat straw.

can be substituted for both forages and concentrates because of their moderate level of neutral detergent fiber (NDF) and highly fermentable carbohydrates (DePeters, Swanson, Bill et al. 2020a). Additionally, citrus byproducts, rich in pectin and sugars, can replace traditional high-energy concentrates (Bampidis and Robinson 2006). California accounts for 79% of the total U.S. citrus production (USDA 2024) with 266,300 bearing acres.

Most respondents (n = 15; 57.7%) reported use of a commercial laboratory to determine the nutritional composition of all byproducts, whereas 42.3% (n = 11) analyzed only some byproducts. Recent work in California (DePeters, Swanson, Bill et al. 2020b) described the high variability of almond hull composition associated with debris content (stick, shell and dirt), underscoring the importance of feed analysis for this commonly fed byproduct. In general, well-defined byproducts (e.g., soybean hulls) exhibit less variability in nutrient composition, while poorly defined byproducts (e.g., vegetable waste) are more variable (Weiss and St-Pierre 2024). This variability may explain why some nutritionists choose to analyze only specific byproducts.

Most (n = 17; 68%) nutritionists reported increased usage of byproducts over the previous five years (2017–2022), with fewer reporting decreased usage (n = 3; 12%) or unchanged usage (n = 5; 20%). Looking into the next five years, 20 nutritionists (80%) thought byproduct usage would increase in California dairy rations, with fewer anticipating decreased (n = 3; 12%) or unchanged (n = 2; 8%) usage.

Byproduct feeding levels

Twenty-three nutritionists reported that all lactating cow rations formulated included byproducts, accounting for more than 898,600 milking cows (one respondent did not report cows serviced). Three nutritionists reported that 50%, 20% or 10% of their lactating cows were not fed byproducts, representing 38,100 lactating cows. Most respondents reported byproduct inclusion in all dry cow (n = 23) and heifer (n = 21) rations, but some respondents reported that not all dry cows and/or heifer rations included byproducts.

The average, maximum and minimum inclusion rates of byproducts in rations, as reported by nutritionists, are presented as a box plot distribution in figure 3. The average inclusion rate ranged from 10% to 80% of diet dry matter (DM) for lactating cows (mean = 39.8%), 5% to 80% of diet DM for dry cows (mean = 35.4%), and from 5% to 80% of diet DM for heifers (mean = 36.0%). The inclusion rate of feedstuffs is likely influenced by many factors; in the current survey, value, availability and price all dictated byproduct usage. In a nationwide survey of university nutritionists, Mowrey and Spain (1999) found individual byproduct usage varied due to local availability and nutritional properties of byproduct feeds. California's expansive land mass likely factors into the large ranges of

Almond hulls were the most commonly reported byproduct fed by California dairy nutritionists. *Photo*: J. M. Heguy.

Cull tomatoes, one of 58 byproducts identified in the survey, illustrate the variety of byproducts available to California dairies. *Photo*: J. M. Heguy.

byproduct inclusion rates, especially as it relates to geographic location of the major milk sheds. The San Joaquin Valley is the largest milk shed in California (fig. 1), is at the heart of agricultural production in the state, and is easily accessible by rail and trucking. The distance between the other milk sheds and broader agricultural commodity production is much greater; proximity and transportation costs of agricultural byproducts is likely a barrier to inclusion in those other parts of the state.

In the current study, average California lactating ration byproduct inclusion rate was estimated at 40.9% (DM basis). We calculated this number by weighting nutritionists' response on average DM byproduct inclusion by the number of lactating animals fed. Naranjo et al. (2020) found a higher lifetime inclusion rate of 49% in five commercial dairies in the southern San Joaquin Valley, assuming four lactations per cow. In comparison, Russomanno et al. (2012) reported an average byproduct inclusion rate of 31.2% across 10 states, including California. Similarly, another study estimated a national average of 32% byproduct inclusion in lactating dairy diets (de Ondarza and Tricarico 2021). The higher byproduct inclusion rates observed in California likely reflect the greater availability of these feedstuffs and the value brought to the ration.

Applications

Byproducts play a crucial role in California dairy rations and contribute to the sustainability of the industry. The estimated average inclusion rate of 40.9% of diet DM highlights their widespread use in ration formulation. As water restrictions tighten in California, more reliance on byproducts to deliver necessary fiber, sugar, fat and protein in rations may drive that inclusion rate higher. In the current survey, this is supported by the 88.5% of nutritionists utilizing almond hulls as a

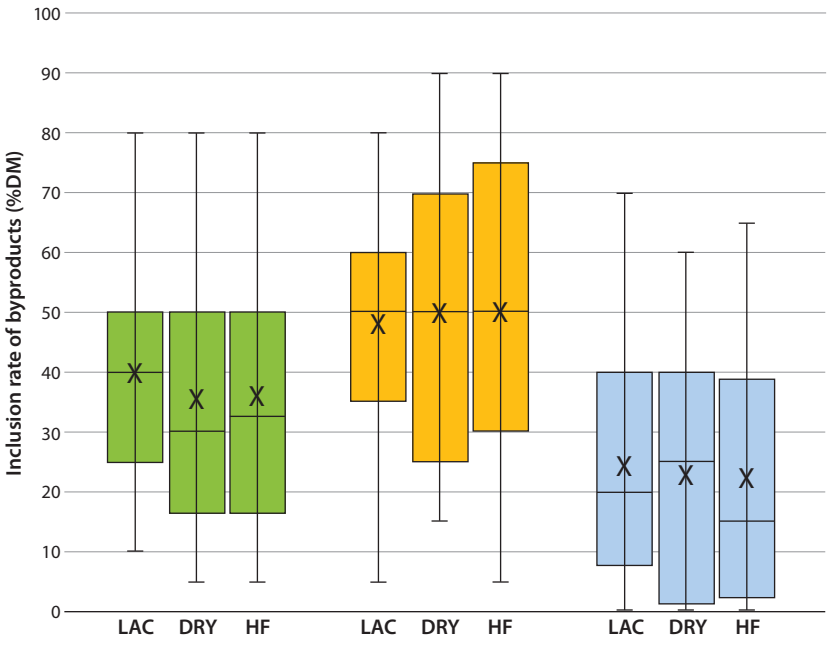

FIG. 3. Box plot distribution of the inclusion rate of byproducts (DM%) in lactating cow (LAC), dry cow (DRY), and heifer (HF) diets. Green, average reported inclusion; yellow, maximum reported inclusion; blue, minimum reported inclusion. Each box plot shows the 50th percentile (median, line within the box), 25th and 75th percentile (box) and range (whiskers). The "x" indicates the mean.

forage replacement. The large range in byproduct feeding rate for lactating rations (0%–80% of diet DM) may indicate an opportunity to increase byproduct inclusion rates in California dairy rations on some farms.

The high rate of byproduct inclusion in California dairy rations contributes to the state's sustainability efforts, not only by reducing environmental impact, but also by enhancing economic viability. All dairy nutritionists selected "value" as a main reason for incorporating byproducts into rations, demonstrating that cost-effectiveness is a driver of adoption and an important component of sustainable dairy production. Byproduct feeding also provides a revenue source to the supplying agricultural industries and utilizes the human inedible components of their products, making those industries more sustainable. CA

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