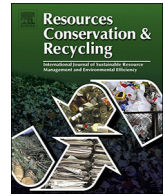




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journal homepage: www.elsevier.com/locate/resconrec

Full length article

A systems examination of school food recovery in Northern Colorado

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ARTICLE INFO

Keywords:

Food recovery
School nutrition
Policy
Food waste
Waste diversion

ABSTRACT

Food recovery is a key strategy to address food waste concerns. School nutrition programs have significant amounts of food waste; yet, little is known about the prevalence and feasibility of school food recovery. In this mixed methods study, we identify potential school food recovery options and relevant systems factors, such as policies, resources, barriers, and competing priorities. To achieve these objectives, we conducted pre-consumer food waste audits and measured all wasted food recovered or landfilled at 14 school kitchens across three Northern Colorado school districts. Additionally, we interviewed professionals engaged in food recovery ($n = 8$) and school nutrition and sustainability staff ($n = 20$). The results indicate that the majority of food waste is landfilled, but food donation through share tables and appropriation of milk to food banks prior to long school breaks were viewed as the most feasible food recovery options. Liability concerns, increased expenses over landfilling, inconsistent wasted food volumes, and policy confusion hindered food recovery. Interviewees also viewed priorities to promote food safety and quality of recovered food as barriers. Key facilitators of food recovery were the desire to facilitate a cultural change to normalize food recovery among students and volunteers or advocates to address the food recovery labor needs. Interview participants across the system agreed that the training process required to sort uneaten foods had secondary benefits of equipping the next generation with environmental stewardship habits. Study findings underscore the interconnected nature of food safety, economics, and food recovery, and also suggest that systems-level solutions are warranted.

1. Introduction

Food waste is a significant problem affecting the environment and the global population. According to the United States Environmental Protection Agency (EPA), Americans produced 39 million tons of food waste in 2015, sending the majority of it to landfills (U.S. Environmental Protection Agency, 2016a). Landfilled food is a key driver of climate change due to the greenhouse gas emissions during the production, distribution and refrigeration of wasted food (Springmann et al., 2018), as well as the methane and carbon dioxide emitted by landfilled food (U.S. Environmental Protection Agency, 2016b). These gases change climate patterns which affect food production, water access, and exposure to health hazards (NASA's Jet Propulsion Laboratory, 2018) and warrants diverting food waste from landfills. In Colorado, seven million tons of solid waste are generated annually (Burns et al., 2016). In Colorado, 16.8 percent of residential and commercial waste is comprised of food, the second most common material landfilled following paper (Burns et al., 2016). The Larimer County landfill in Northern Colorado is predicted to reach capacity in 10 years

if current and projected trends for disposal of solid waste continues (Sloan Vazquez McAfee Municipal Solid Waste Advisors, 2016).

In order to better manage natural resources, the EPA developed the Food Recovery Hierarchy (U.S. Environmental Protection Agency, 2016c). Food recovery refers to strategies to prevent and divert wasted food from landfill disposal (U.S. Environmental Protection Agency, 2016c). Following the reduction of surplus food, the hierarchy recommends, in order of importance, feeding hungry people, feeding animals, industrial uses, and composting as landfill alternatives (U.S. Environmental Protection Agency, 2016c). Important considerations for food donations are proper food handling and food safety (McFadden et al., 2015). There are also increasing food safety concerns with feeding food scraps to animals, and this practice has dwindled considerably since the 1980s when a number of animal-feed related disease outbreaks occurred (Harvard Food Law and Policy Clinic, 2016a). Industrial uses include recycling food to create value-added products through anaerobic digestion, which is the system where microorganisms decompose organic materials including food scraps in the absence of oxygen (The Environmental Research and Education Foundation,

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E-mail address: mpp22@illinois.edu (M.P. Prescott).<https://doi.org/10.1016/j.resconrec.2019.104529>

Received 9 June 2019; Received in revised form 26 September 2019; Accepted 30 September 2019

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2015). This process yields biogas, a renewable energy source (U.S. Environmental Protection Agency, 2016d). Digestate, a combination of a solid and liquid, is also produced through anaerobic digestion (U.S. Environmental Protection Agency, 2016d). It is nutrient dense and can be used as a soil amendment, fertilizer, and livestock bedding (U.S. Environmental Protection Agency, 2016d). Besides anaerobic digestion, liquid fats and meat byproducts such as grease also can be used as ingredients to make cosmetics and soap in the rendering industry (U.S. Environmental Protection Agency, 2016d). As well, the fat and meat byproducts can be transformed into biodiesel fuel (U.S. Environmental Protection Agency, 2016d). Composting is a way to divert food scraps, particularly those not suitable for food donation, from the landfill and produce healthy soils (Harvard Food Law and Policy Clinic, 2016b; U.S. Environmental Protection Agency, 2016e). On-site composting requires infrastructure to hold the food waste and provide an environment to support the decomposition process (Town of Mansfield, 2002). Three common types of on-site composting systems are holding units, turning units, and enclosed bins to generate nutrient-rich soil (Cornell Waste Management Institute, 2019). Food waste can also be hauled by waste management vendors to commercial composting sites that often accept a larger volume and variety of food wastes including meat and dairy that are processed into a soil amendment (Prepared and submitted by Seven Generations Ahead on behalf of the Illinois Food Scrap Coalition, 2015).

Institutions, including schools, are major sources of food waste (Hoover, 2017). School food waste consists of both pre-consumer and post-consumer food waste. Sources of pre-consumer food waste include overproduction, product expiration, trim waste, spoilage, contaminated items, and substandard items (Prescott et al., 2019). Pre-consumer waste rates are relatively low across schools, but schools sporadically have days of high pre-consumer waste volumes due to difficulties in forecasting student demand (Prescott et al., 2019). Post-consumer waste, also known as plate waste, are served foods that students discard. Rates of post-consumer waste are much higher and more consistent than pre-consumer waste (Prescott et al., 2019; Shanks et al., 2017). Since the National School Lunch Program serves meals to over 30 million children per year (U.S. Department of Agriculture, Food and Nutrition Service, 2017), changes to promote school food recovery have the potential to play a significant role in delaying landfill capacity and reducing greenhouse gas emissions. For example, the United States Department of Agriculture (USDA) allows schools to implement share tables to reduce food waste and provide nutritious food for hungry students (U.S. Department of Agriculture, 2016b). Share tables are locations where students can place unwanted food or beverages that another student can take and must be in compliance with the state and local health food codes (U.S. Department of Agriculture, 2016b). The USDA also allows schools to provide food donations to eligible non-profit organizations and in some cases remaining share table items can be donated (U.S. Department of Agriculture, 2012). Unclaimed share table items can also be reused in future meal service, where permitted by local health codes (U.S. Department of Agriculture, 2016b; Colorado Department of Education, 2016).

There is emerging evidence on food recovery barriers, including food retailers' liability concerns, fragmented food safety guidelines, food safety concerns, insufficient transportation and storage availability, and additional costs incurred from food donations (Rethink Food Waste Through Economics and Data (ReFED), 2016; Buzby et al., 2014). Yet little is known about school food recovery despite the well-documented high rates of school meal plate waste (Haas et al., 2014; Smith and Cunningham-Sabo, 2014; Schwartz et al., 2015; Cohen et al., 2014). The purpose of this study was to identify 1) potential school meal food recovery options and their prevalence across three Northern Colorado school districts and 2) systems factors, such as policies, facilitators, barriers, and competing priorities, influencing school food waste recovery in these school districts.

2. Methods

This was a mixed methods study featuring a multiphase design (Zoellner and Harris, 2017), where concurrent qualitative and quantitative data were collected across three Northern Colorado school districts, followed by a second phase of qualitative inquiry among individuals engaged in food recovery in a professional capacity in the same region of the state. In addition, this study used a systems approach (Luke and Stamatakis, 2012) to better understand school meal food recovery. A systems approach examines the interaction among the various heterogeneous elements being studied and the emergent properties that are not explained by the individual elements alone. In this study, the emergent properties are the facilitators, barriers, and competing priorities, influencing rates of school food waste recovery, as these are best identified by examining the overall system.

2.1. Phase 1

The methodology for the concurrent qualitative and quantitative data phase has been previously described (Prescott et al., 2019). Briefly, researchers selected the three school districts based on their variation in student demographics, enrollment, and kitchen types. Four trained researchers collected the quantitative data, which consisted of structured kitchen observations of lunch production and corresponding pre-consumer food waste measurement (Prescott et al., 2019). The researchers observed each school kitchen for one day from the end of breakfast service until lunch service and subsequent clean-up ended. One district had a centralized production kitchen, which was observed from open to close for two days. The district centralized production kitchen staff cook food from scratch for all of the schools in the school district and deliver prepared school lunch entrees to individual schools. (There are no schools co-located with the district centralized production kitchen.) The food waste measurement portion of the structured observations involved documenting each wasted pre-consumer food item, the location where waste occurred, loss reason, whether the food was edible, the disposal method, and the food weight or volume. In addition to food recovery options, food and liquid discarded via the garbage disposal were tracked separately from landfilled waste. (According to personal communication with the local municipality, 60% of organic garbage disposal waste is sent to the anaerobic digester and the rest is landfilled.) We also used the same methodology to document foods recovered from share tables at the end of meal service. The qualitative data consisted of interviews with kitchen-level managers, district directors and/or assistant directors of nutrition services, and district-level environmental sustainability coordinators or directors. We collected Phase 1 data from October 2016 to April 2017.

2.2. Phase 2

Phase 2 was exclusively qualitative, utilizing a combination of purposeful (Creswell, 2013) and snowball sampling techniques (Glesne, 2011). Using data from Phase 1, we identified key organizations involved in food recovery (not necessarily recovering school food) and/or implementing food recovery policies, such as the local food bank and state office of school nutrition. We used professional titles to identify potential interview participants from agencies/workplaces involved with food recovery. Interview participants were asked to identify additional individuals working in food recovery, who were recruited until data saturation was achieved. In accordance with the purposeful sampling strategy, one to two interviews per hierarchy level were collected to ensure all food recovery categories were included. Data saturation was achieved when all hierarchy levels were combined (Merriam, 2009). The research literature, (U.S. Environmental Protection Agency, 2016c; McFadden et al., 2015; Harvard Food Law and Policy Clinic, 2016a, Harvard Food Law and Policy Clinic, 2016b; U.S. Department of Agriculture, 2016b; U.S. Department of Agriculture, 2012; Colorado

Department of Education, 2016; 104th Congress, 1996; U.S. Department of Agriculture, 2016; U.S. Cooperative Extension System (eXtension.org), 2016a; Anon., 2013; U.S. Cooperative Extension System (eXtension.org), 2016b; U.S. Environmental Protection Agency, 2016f; Rethink Food Waste Through Economics and Data (ReFED), 2017; Academy of Nutrition and Dietetics, 2016) qualitative research interview guidelines (Merriam, 2009) and the Phase 1 interview protocols (Hollins, 2013; Silvennoinen et al., 2015; Engstrom and Carlsson-Kanyama, 2004; Costello et al., 2015; Loke and Leung, 2015) informed the development of the Phase 2 interview protocol. Phase 2 data were collected from February through May 2017. If scheduling did not allow for an in-person interview, interviews were conducted over the phone. All participants agreed to have their interview audio recorded. The Institutional Review Board at Colorado State University approved the study. All interview participants provided written informed consent.

2.3. Data entry & analysis

Audio recordings were transcribed verbatim, and each transcription was reviewed against the audio recording to ensure content accuracy. Themes were identified using inductive content analysis (White and Marsh, 2006). Two researchers developed a priori codes and their operational definitions based upon the research question. To assess the initial coding scheme, two researchers independently reviewed one kitchen manager, one district director, and one sustainability staff interview transcription. Each reviewer identified important ideas from each interview transcription, and codes were assigned to each meaningful unit using ATLAS.ti (Anon., 2019). The two researchers discussed the initial codes, made some refinements based upon emergent themes, and then reached consensus on a final codebook used for the remainder of the analyses. Remaining interview transcriptions were independently coded by these same researchers. All interview, observation, digital photograph, and document collection data were triangulated to examine consistencies and discrepancies across data sources. All codes were reviewed to uncover patterns; a summary of these overall thematic patterns was provided to interview participants for respondent validation (Lincoln and Guba, 1985). For the quantitative data, descriptive statistics were used to describe common food recovery behaviors. Recovered food waste totals were standardized by dividing the total food wasted by the annual average daily participation rate for each school or district.

3. Results

The Phase 1 data sample consisted of three district nutrition services directors, 14 kitchen-level managers, and 3 district-level sustainability staff. On average, school district interview participants had 5.0 years of experience at their current positions. The titles, work setting, and work experience of the eight Phase 2 food recovery professionals are listed in Table 1. Using data from both phases, Fig. 1 displays the food recovery processes available to schools in Northern Colorado. Both pre- and post-consumer waste could be recovered by pig farmers, composting, and/or anaerobic digestion. Available food recovery pathways were also influenced by available resources and infrastructure. One of the sampled school districts had recently discontinued their off-site commercial composting contract due a 211% increase in hauling costs in just one year. Similarly, the regional anaerobic digester recently closed permanently, making this recovery option unavailable. The food bank only recovered school pre-consumer waste; however, the USDA and state of Colorado Office of School Nutrition permit unclaimed share table items, which are post-consumer waste, to be donated to food banks and other non-profits. But, none of the school districts were currently donating unused share table items externally. Fig. 1 also illustrates the important role the food bank plays in food recovery. All donated foods, from schools and elsewhere, are screened at the food bank to determine

Table 1
Food Recovery Professional Interview Participant Job Titles and Years of Experience (n = 8).

Title (Work Setting)	Years in Current Position
Sustainability Coordinator (Waste Hauling Company)	7 years
Animal Feed Regulatory Administrator (State Government)	3 years
Food Resource Manager (Food Bank)	2 years
Extension Specialist (University)	9 years
Environmental Health Specialist (County Government)	25 years
Manager (Commercial Composting, Biogas Facility)	2 years
School Nutrition Program Specialist (State Government)	1 year
Solid Waste Management Unit Staff (State Government)	2 years

whether they are appropriate for human consumption and utilized accordingly.

3.1. Food waste measurement results

Three-fourths of the pre-consumer food waste generated during the kitchen observations of lunch production was landfill disposed (Fig. 2). Compost rates were driven by the district centralized production kitchen, which was the only location with composting available. Of the landfilled food, 71.19% was initially considered edible; however, 37.32% of this food was originally self-served. (Once food is put out for self-service, potential food safety risks prevent using any leftover items that were served, but not selected, for future human consumption.) While food recovery was uncommon for pre-consumer food waste, three of the 13 schools engaged in one form of post-consumer food recovery, share tables. There were a total of 2.01 of beverages (6.86 ml/average student meal) and 5.28 kg of solid foods (13.28 g/average student meal) recovered from breakfast and lunch share tables consisting of milk, juice, apples, oranges, packaged breakfast entrees (i.e. breakfast loaves, muffins), and string cheese. None of these leftover share table items were landfill disposed; items were either reused for future meal service or given to the school nurse to distribute to hungry and/or sick children. There were no items placed on the share table at one school, which was typical according to the school staff. This particular share table was located away from the lunch line and above child eye-level. The other two share tables were located immediately past the point of purchase or on the condiment table. None of the existing share tables featured promotional signage or other visible instructions for use.

3.2. Interview results

Interviews revealed three main facilitators to school food recovery at the pre- and post-consumer level (Table 2). First, interview participants viewed schools as a critical vehicle to create a cultural shift to normalize food recovery; interviewees across the system agreed that the training process required to sort uneaten food items had secondary benefits of equipping the next generation with environmental stewardship habits. Second, champions, advocates, and/or volunteers to help address the extra time burden, real or perceived, associated with sorting food waste and training students to sort waste were also identified as key facilitators to food recovery. However, this facilitator was operationalized differently across institutions. At schools, student clubs and passionate school staff members enabled successful food recovery endeavors, whereas, the food bank relied upon a large volunteer base to sort donated foods. Third, interview participants also shared several policies that facilitated food recovery, such as the Bill Emerson Good Samaritan Food Donation Act and the USDA Share Table Memorandum. A complete summary of all policies that interview participants felt

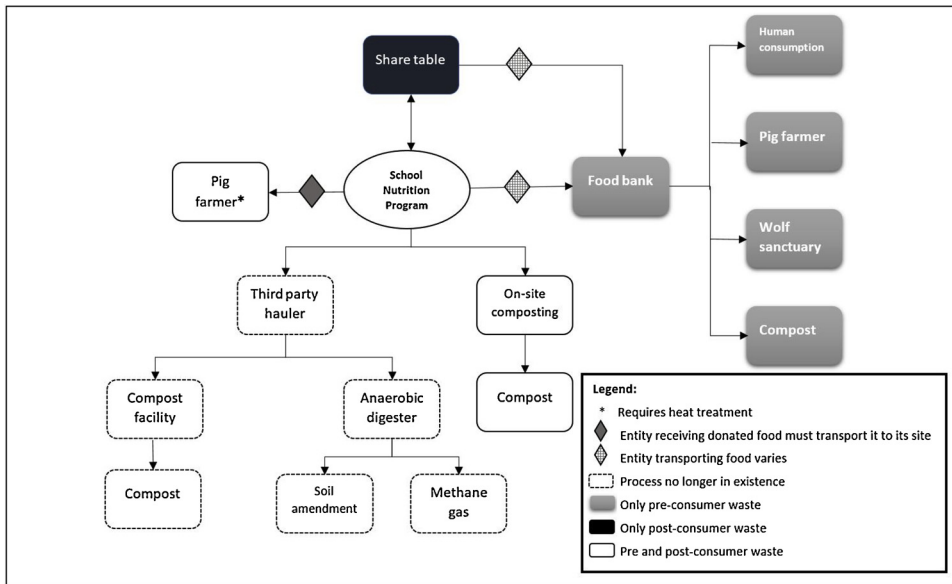


Fig. 1. Possible food recovery pathways for three Northern Colorado school districts, demonstrating the complexity of options and acknowledging that available pathways change over time depending on infrastructure, resources, and policies. Share tables are locations where students can place unwanted food or beverages that another student can take and must be in compliance with the state and local health food codes (U.S. Department of Agriculture, 2016b).

impacted food recovery is provided in Table 3.

Analysis of interviews revealed four main barriers limiting school food recovery (Table 4). First, food recovery was, or appeared to be, cost prohibitive. Additional resources are required to transport food safely for human consumption, heat treat wasted food fed to pigs, purchase on-site composting systems, and haul food waste to commercial composting and/or industrial uses site. These costs are exacerbated by the low cost of landfilling food waste. Second, the inconsistent volume and types of wasted school food was another recovery challenge. There is wide variation in the amount of school pre-consumer food waste generated each day, limiting the feasibility of routine transport of food donations to nourish humans or animals. While plate waste rates are more constant, the wide range in the nutritional values of uneaten foods limits the perceived suitability of feeding this waste to dairy herds. Third, food recovery is also stymied due to the potential negative impact on school nutrition programs' reputation and liability risk. Since they have no control over food once it is donated, interview participants expressed concern over potential food safety risks, such as poor temperature control in human donation sites and the potential failure of pork farmers to heat-treat food donations. In addition, school nutrition programs perceived a waste stigma,

where the community might view the donation of tax dollar-funded foods unfavorably. Lastly, school-level staff members were confused about what types of food recovery activities were permitted. This confusion stemmed from both knowledge gaps about whether health codes permitted food recovery, as well as what was allowed since school food products are government subsidized.

In addition to these barriers, there were two main competing priorities that also limited food recovery activities (Table 4). Schools and food recovery agencies indicated that food safety concerns limited human and animal food donations. Interview participants universally agreed that food safety concerns trumped food recovery priorities. Similarly, food quality standards also conflicted with donating school food items for human consumption. Concern for the quality of donated foods was driven partly to protect the reputation of school food programs and also to promote the dignity of the individuals consuming the donated foods.

3.3. School food recovery feasibility results

Given these barriers, facilitators, and tradeoffs, some food recovery initiatives had limited feasibility. Currently there is not enough regional

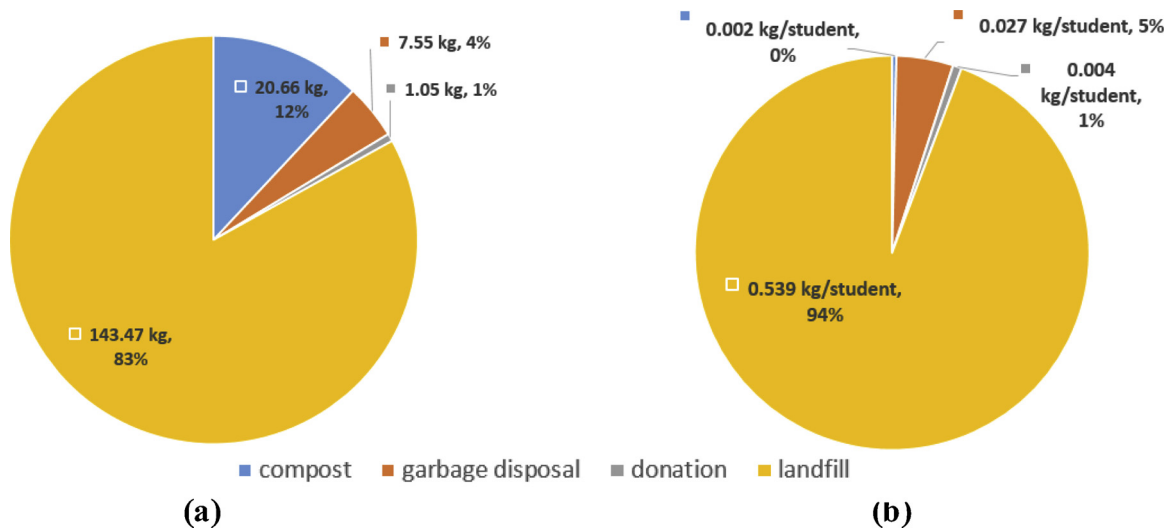


Fig. 2. Volume of solid food recovered and landfilled among 14 school and district kitchens on 15 days of pre-consumer waste tracking across three Colorado school districts: a) total weight of food discarded (kg), b) total weight (kg) standardized by average number of student meals served.

Table 2

School food recovery facilitators and representative quotes from district and school staff (n = 20) and food recovery professionals (n = 8) participating in interviews about school food waste and recovery.

Systemic Facilitators	Illustrative Quotes
Desire to facilitate a cultural change	I think the educational opportunity to get children, getting students, even teachers, thinking about beneficial ways of managing their waste and food waste recycling is beneficial. - Sustainability Coordinator (Waste Hauling Company) So the big challenge for us right now is to find a cost effective way to compost and really help students understand the full life cycle of what we [use], even at home. - School District Sustainability Manager We had our learning services directors identify 3 schools that were more green-oriented, to really focus on those, find out what they're doing, how they're building that culture within their school and kind of taking lesson learned and figuring out how we can build momentum throughout the rest of the district. - School District Sustainability Coordinator
Volunteers or advocates to address labor needs	It's just about getting somebody [to] champion it... If you do commercial hauling then you have to have a, like a custodial staff on board and the kitchen staff on board. But with the Earth Tubs, ^a somebody just [does the stirring] once a day or once every few days or something like that. - Solid Waste Management Unit Staff (State Government) We have a really, really, strong volunteer base that will sort those grapefruit into rotten and useable [piles] and put the useable ones out on the distribution line. - Food Resource Manager (Food Bank) [Named custodian] is actually the one that went to [the District Nutrition Director] and said we have so much food that's just thrown away. Can we, if it's inspected and it is still good and all that, can they share? So she really is looking for opportunities [to reduce waste]. - School District Sustainability Coordinator [A waste reduction champion] doesn't necessarily have to be one person, it's just usually is what we see is one person that really takes it on, makes it their own a little bit. - School District Sustainability Coordinator
Policies that support food recovery.	Schools do have regulations and you know they have to be careful. But I think the state regs have really [re]laxed, loosen up, made it okay. I think [on-site composting] is feasible and I think it is a good idea. - Sustainability Coordinator (Waste Hauling Company) We exempt five cubic yards of food waste and up to a 100 cubic yards of yard waste... So, we also allow in-vessel, which sometimes you have little Earth Tubs. ^a We allow up to 10 cubic yards of food waste in process if it's in one of those. - Solid Waste Management Unit Staff (State Government) So we for a long time, we actually had a requirement that they register with us they had to do something, they had to attain what's called financial assurance. They had some other requirements that I thought a lot of those requirements were too burdensome. So, I said well, we'll exempt the certain amount of food waste to be composted on site and allow that to occur without any kind of notice to us. - Solid Waste Management Unit Staff (State Government) Within certain circumstances a share table item can be used as a part of another reimbursable meal. - School Nutrition Program Specialist (State Government) One practice that's USDA encouraged is the ability to use leftovers foods- being able to sell [the leftovers] à la cart. And, the USDA puts guidance out [saying] basically any food sold à la carte has to meet specific nutrition standards. If it is part of a reimbursable meal, school can sell this the day of or day after. They will be exempt from Smart Snacks standards, [which] encourages them to use the leftover entrée items. - School Nutrition Program Specialist (State Government) There is the good Samaritan act that allowed food to be given away without risk of liability barring gross negligence. - School District Director But [the food bank is] funny on dates too... I understand I; they want to keep [food] safe. We have protection under the Richard B. Russell act that we can donate food and are free of legal liability when we're doing that to another non business production. - School District Director

^a Earth Tubs are compact in-vessel composting systems (Puyallup Research and Extension Center at Washington State University, 2019).

volume to make the third-party hauling that is required for off-site composting and/or biogas production cost effective for schools. In addition, the local digester permanently closed due to public complaints about odors, air quality regulation infractions, and other permitting violations (Sweeney, 2016). Onsite composting is more feasible, but rodents, odors and staffing concerns are important challenges. Contamination concerns may make pre-consumer waste the most optimal food recovery source, particularly for on-site composting. The district that had a centralized production kitchen uses five compost tumblers for their pre-consumer waste. These composters are less expensive compared to other on-site options but require a significant amount of manual labor to operate. Another district views onsite in-vessel anaerobic digestion as the most feasible composting system since it is self-contained, mitigating the odor concerns. This district was researching grant funding for this composting system; although in-vessel anaerobic digestion systems are very expensive, the long-term cost is less than the current annual third-party hauling contract fees. While commercial dairy farms are not feasible recovery solutions, wasted school food could potentially be donated to small-scale pig farmers as long as the farmers agreed to heat treat the waste. Most school nutrition staff did not view daily food donations to food banks as feasible, nor always necessary. Yet, all three districts discussed donating unused milk to food banks immediately prior to school breaks (i.e. winter break, summer vacation, etc.).

Multiple food recovery professionals emphasized that prevention of

food waste generation was more important than food recovery endeavors. One commercial waste hauler said, "There is more demand to divert [food waste from landfills] than there is demand for compost." One animal expert agreed, saying, "If you really want to make an impact, it's how much [waste] we produce... I think there might be some avenues to do things with feeding [wasted food] to animals, but I don't think that's the solution."

4. Discussion

This mixed methods study examined potential school meal food recovery options across three Northern Colorado school districts. These study results demonstrated that school food recovery was relatively uncommon in Northern Colorado. While school nutrition and food recovery staff were overall supportive of school food recovery, they cited barriers, such as food recovery costs, liability concerns, knowledge gaps on relevant policies, and logistical challenges related to inconsistent waste volumes, that prevented or hindered food recovery. School share tables had the fewest reported barriers, suggesting that it is the most viable school food recovery option. In addition, share tables provide a rare and much-needed opportunity for landfill diversion of post-consumer school food waste. However, the relatively high rate of pre-consumer waste that was composted at the one district's centralized kitchen, suggests centralized cooking facilities are ideal locations to recover inedible food for animal feeding, anaerobic digestion, or

Table 3
Summary of all policies reported by interview participants (n = 28) as impacting school food recovery.

Policy	Brief Summary of Policy Relevance to Food Recovery
Bill Emerson Good Samaritan Food Donation Act	In 1996, the Bill Emerson Good Samaritan Food Donation Act was enacted providing liability protection to food donors, stipulating that the donor has not given away the product with the intent to harm (104th Congress, 1996). Through this federal act if the contributor has donated in good faith, the nonprofit is not responsible for any damages due to food related sickness (104th Congress, 1996).
U.S. Federal Food Donation Act	In 2008 the U.S. Federal Food Donation Act extended the reach of the Good Samaritan Act (Federal Food Donation Act of 2008, 2008). The Food Donation Act encourages federal organizations to donate surplus, nutritious food to feed Americans without dependable access to adequate, safe, and healthy food (Federal Food Donation Act of 2008, 2008).
USDA Share Table Memo	The USDA allows share tables (i.e. locations where students can put unwanted packaged items or whole fruit or vegetables allowing their uneaten food items to be "shared" with other students) in all child nutrition programs (U.S. Department of Agriculture, 2016b). However, the USDA requires that school districts seek guidance from their local health department to ensure share tables are operated according to local health codes (U.S. Department of Agriculture, 2016b).
Colorado, state law C.R.S. §§ 13-21-113	This Colorado state law offers liability protection for food donors (Donation of items of food-exemption from civil and criminal liability, 2013). It specifies that organizations that donate food are not liable for damages related to the condition of the food, given that that the donation was made responsibly to nonprofits (Donation of items of food-exemption from civil and criminal liability, 2013), encouraging statewide donations of extra food.
Foods taken from schools	State-level administrative policy requiring all unused school foods to be documented as donated or disposed of and cannot be taken home by school nutrition staff. (Texas Department of Agriculture: Food and Nutrition Division, 2018) This is to prevent intentional overproduction.
Local health codes	These policies guide safe food production and storage and vary at the state, county, and/or city level. Local health codes typically include utilizing time and temperature protections to ensure food safety (US Food and Drug Administration, 2019; US Food and Drug Administration, 2017), and these requirements are particularly relevant to the transport of donated food to food banks or other non-profits.
Food Safety Modernization Act Final Rule for Preventive Controls for Animal Food	The U.S. Food & Drug Administration (FDA) issued this final rule necessitating that animal food processing facilities maintain a food safety plan that analyses hazard risk to identify which hazards need control measures to reduce or stop spread of disease (U.S. Food and Drug Administration, 2017). In regards to food recovery, this rule applies to animal food businesses to protect public health (U.S. Food and Drug Administration, 2017). This rule only concerns commercial animal food processors and not for example, small family farmers feeding their animals scraps from the dinner table (U.S. Food and Drug Administration, 2017).
Swine Health Protection Act	This act requires food waste containing meat scraps fed to swine be sufficiently heat treated to eradicate disease causing bacteria protecting human and swine health (U.S. Department of Agriculture and Animal and Plant Health Inspection Service, 2016).
FDA Bovine Spongiform Encephalopathy (BSE)/Ruminant Feed Ban Rule	This Food and Drug Administration (FDA) rule forbids adding mammalian protein into ruminant animal feed to prevent Bovine Spongiform Encephalopathy (BSE), a neurologic disease, from re-occurring. Ruminant animals include cows, sheep, and goats (U.S. Food and Drug Administration (FAD), 2016; Substances Prohibited from Use in Animal Food or Feed, 2016).
Association of American Feed Controls Officials	To further regulate animal feed, the FDA partners with state and local entities chiefly the Association of American Feed Control Officials (AAFCO) to enforce uniform feed terms and ingredient definitions ensuring safe feed (U.S. Food and Drug Administration, 2015). AAFCO provides official guidance in how to interpret and enforce laws governing animal feed production (Association of American Feed Control Officials, 2019), assuring trustworthy feed (U.S. Food and Drug Administration, 2015). Based on the AAFCO 2017 Official Publication, school food waste must meet the AAFCO restaurant food waste standards, which require food to be free of plastic ware and other non-food items and nutritionally analyzed in order to be used as animal feed (Association of American Feed Control Officials, 2017).
Colorado animal feed regulations	These state-level regulations specify that no garbage can be fed to swine unless it has been thoroughly heat treated and a permit must be obtained from the state agricultural commission (Garbage cooking, 2016; Anon., 2016). Garbage is defined as all animal and produce waste excluding vegetable products like leaves or tops that have not been combined with other waste (Definitions, 2016).
Colorado compost regulations-6 CCR 1007-2	Colorado regulates composting facilities containing greater than five cubic yards of food waste onsite or greater than 10 cubic yards when composed in vessel (Colorado Department of Public Health and Environment, 2017). Therefore, on-site school composting generally would not need to follow any additional regulations.
State compost laws	States differ in their composting regulations, and there is not an overarching federal composting law (Rethink Food Waste Through Economics and Data (ReFED), 2017).

compost. One of the key facilitators to school food recovery was the desire to facilitate a cultural change to normalize these behaviors. Study participants reported being willing to put in the extra time required to train students to divert wasted food in order to instill food recovery habits in the next generation.

The reported barriers to school food recovery are largely similar to those previously reported (Rethink Food Waste Through Economics and Data (ReFED), 2016; Buzby et al., 2014; U.S. Food and Drug Administration, 2017; U.S. Department of Agriculture and Animal and Plant Health Inspection Service, 2016; U.S. Food and Drug Administration (FAD), 2016; Substances Prohibited from Use in Animal Food or Feed, 2016; U.S. Food and Drug Administration, 2015, Association of American Feed Control Officials, 2017; Garbage cooking, 2016; Anon., 2016, Saleemdeb et al., 2017). In a 2016 report on food

waste reduction, food retailers' top food recovery barriers were potential liability and negative press coverage in the event of someone getting sick from donated food, fragmented regulation of the FDA Food Code, increased handling costs beyond landfilled waste disposal, and logistical challenges associated with handling, transporting and storing donated food (Rethink Food Waste Through Economics and Data (ReFED), 2016). However, these barriers to school food recovery seem to be exacerbated by the government-funded nature of the food served in school meals. In the current study, school nutrition programs were concerned that the donation of excess food would result in stigma from the perception that schools are not using tax dollars efficiently.

In this study, food safety priorities inhibited food recovery goals, and a similar tradeoff was found in a study examining barriers to the reduction of pre-consumer school food waste (Prescott et al., 2019).

Table 4

School food recovery barriers and tradeoffs: Representative quotes from interviews with school district staff (n = 20) and food recovery professionals (n = 8).

Systemic Barrier or Tradeoff	Illustrative Quotes
Increased food recovery costs relative to low landfill cost	<p>I think the big issue is that landfilling is really cheap. So because of that it makes food waste composting look very expensive. So like one of the ways that people have recommended is to manipulate the cost so even though landfill is cheap to make it balance out or sell it as a package deal. But, I think that's the hard part is that people are okay to pay for trash, but they're not really as willing to pay for anything outside of that like composting or recycling. - Sustainability Coordinator (Waste Hauling Company)</p> <p>I think food waste is important; I think it is important to recycle it. But, someone has to pay for it. - Sustainability Coordinator (Waste Hauling Company)</p> <p>One of the things as we were trying to understand is the 100% increase in cost [for off-site composting]. That's kind of a touchy subject... But, we felt like we were legitimate in saying, 'What is the cost for doing this? What are you taking into account for cost?' Then we did say to them, 'You need to tell us what the carbon footprint is to put it in the landfill versus you to transport it?' Because we knew that had to be part of our decision. - School District Sustainability Manager</p> <p>It's difficult to talk about other advantages [of food recovery], at least for producers. Because it's all gonna depend on what are the nutritional benefits of the [recovered food] being [fed to the animals] and what are the price points... So it'll have to be economically feasible, as well as nutritionally sufficient to provide what [the livestock] need. - Animal Feed Regulatory Administrator (State Government)</p> <p>[The in vessel aerobic digester] will compost 100 pounds of food down to 10 pounds of material that you can mix with top soil and do top dressing of athletic fields in 24-48 hours. Our goal would be to have one at each of the 13 schools [that were] composting when we stopped the program. But it's just the cost of that, so right now we're doing a lot of research on grants. There are some options for leasing, which typically that's not something that a school district wants to get into because we just don't know what our funding is going to be year to year. - School District Sustainability Manager</p> <p>I think that [composting post-consumer waste] would probably take more extra manpower... No, I think that would not fly here. With the budgets that we live on it would be up to maintenance [to compost] and I think that's a whole different area than me. - School Kitchen manager</p>
Inconsistent product or volume	<p>School lunches and stuff like that would be a little bit harder to feed dairy cows... The consistency [of what is served] varies from day to day, and the last thing that you want to do in a dairy cow's diet is to change consistency, because that affects not only production of milk, but also health. - Extension Specialist (University)</p> <p>The problem with larger production systems is the consistency in the supply. For example, if you are a farmer and you have a 1000 pigs, are you going to get enough [school food waste] every day? Because [farmers] need to plan ahead. - Animal Feed Regulatory Administrator (State Government)</p> <p>The food bank will only come if it is a certain amount of food or if it is unopened and unspoiled. - School District Director</p> <p>We have reached out to some churches, [but] we don't have enough waste for them to come pick it up. - School District Director</p> <p>The composting facilities are very strict on contamination. If you get too much contamination, they will start rejecting the load. - School District Sustainability Manager</p>
Liability	<p>"We cannot control once it leaves here- at what temperature it's at till it gets to where it's going. And if it's bad, then it's going to fall back on us. So, no, we don't [donate unused food]. - School Kitchen Manager</p> <p>"It's more of a stigma around [the food donation], it's seen as our [school's] waste, and we should be controlling that. And so the idea of giving it to somebody else is something that we should not be doing because we should be controlling that waste in the first place. So, it's when you have unpredictable days or when you have new menu item days, it's a challenge to not see that [unused food] go somewhere when you know that there's so many places that could use it. So, honestly... if there were any policies that I could see change so that we can help others more, that's one. - School Kitchen Manager</p> <p>We don't want the public to assume we're purchasing excess and over producing and then donating these things and they're buying it and they're paying for it and funding it. So, it's a gray area. There is definitely a need for an outlet for [food recovery]; I just don't know the avenues to get there. - School District Director</p> <p>No, [we don't donate any food] because if there was anything wrong with the quality of it when I got there- sue is a big word. Seriously, 'I got this from this school district and I got sick.' Tadaa, lawsuit. - School Kitchen Manager</p> <p>I don't want to create a situation where I have pathogens being multiplied in swine. I'm not saying it's [the] responsibility [of a school district to heat treat the food waste], but can I trust every single backyard pig owner? Probably not. -Animal Feed Regulatory Administrator (State Government)</p>
Policy confusion	<p>We need to find out what we could do with the food and stuff. Can we give it to the neighbors for them to compost at home? Or can we just use it for the school garden? What exactly can be done since all the food is government funded? We just have to check out the rules. - School Kitchen Manager</p> <p>[Food donation] is a tricky area. So, I've asked if we can then take that food, package it, and take it to [the church soup kitchen], or the women's shelter - somewhere we know they're serving meals. Our food has been held at a safe temperature for a safe amount of time. There is nothing that's wrong with it that it can't be served. Over the summer during summer feeding I was doing this. There is just a big gray area as far as using food that was bought with tax dollars, to donate it. - School District Nutrition Director</p> <p>No, [we haven't ever done a share table here.] I don't think that's legal because other kids might have something going on health-wise, and they had touched that food. - School Kitchen Manager</p>

(continued on next page)

Table 4 (continued)

Systemic Barrier or Tradeoff	Illustrative Quotes
Food Safety versus Food Recovery	Sometimes you don't how long that milk has been sitting [on the share table]. It could have been there for an hour. So, I stopped doing [the share table] at [my previous school], and I never started here. - School Kitchen Manager [We have] people who lay eyes on the food and make sure that it is safe and not rotting. Anything that is too far gone to be salvaged goes into our compost... What we are looking for is food safety... If there's an apple that has a bruise on it, we leave it. If there is a pepper that has fallen and broken open, we probably won't put that out. Likewise, if there is milk that's spilling or leaking, we don't put that out. But, if it is a day or two past date, we will put it out. - Food Resource Manager (Food Bank) If someone brings in meat, for example that clearly was frozen and is beginning to thaw, that's a pretty significant amount of time that it must have been out of freezer temperature... We will usually accept it and then give it to the wolf sanctuary because that's not human consumption so their regulations are much more lax. - Food Resource Manager (Food Bank) For certain viral diseases, pigs are amazing amplifiers. So you feed it to a pig in its raw form, and the pig will multiply it like you have no idea. So, that's risky. And you would hope that food served for school lunch are properly cooked, but you want to make sure that there is no contamination along the way. - Animal Feed Regulatory Administrator (State Government)
Food Quality versus Food Recovery	Yeah, I think food safety and food quality is too much of an issue to have some... to take spaghetti or something to a food bank or a shelter or something like that. I think it would be too much of an issue. - School Kitchen Manager We don't want to put rotten things out on our distribution lines because that is a big part of, you know feeling empowered, feeling not marginalized. If you are coming to the food bank for food, you have enough of that already, and you shouldn't have to sort through rotten food to get the good stuff. - Food Resource Manager (Food Bank)

Animal feed policies aiming to keep food safe, such as the Swine Health Protection Act and FDA Bovine Spongiform Encephalopathy (BSE)/Ruminant Feed Ban, seemed to hinder food recovery feasibility among our study participants, which is consistent with the literature (U.S. Food and Drug Administration, 2017; U.S. Department of Agriculture and Animal and Plant Health Inspection Service, 2016; U.S. Food and Drug Administration (FDA), 2016; Substances Prohibited from Use in Animal Food or Feed, 2016; U.S. Food and Drug Administration, 2015, Association of American Feed Control Officials, 2017; Garbage cooking, 2016; Anon., 2016). Donation of prepared food is particularly challenging due to the limited time span to inhibit growth of pathogens in (or ensure safety of) previously prepared food (Weymes and Davies, 2019). The recovery of unopened, packaged foods, such as milk, do not share this limitation, which is consistent with the current study findings of share tables and milk donation prior to school holiday breaks viewed as feasible by study participants. Even though study participants purported share tables as feasible, the amount of share table food diversion was low at some schools, and many school nutrition staff were unsure of whether share tables were permitted under local health codes. These findings suggest schools need assistance with share table marketing and outreach to engage students, school staff, and nutrition services staff in share table implementation. In addition, local health inspectors should be involved in developing share table standard operating procedures so that they are in line with health codes.

The interconnected nature of food safety, economics, and food recovery warranted the systems approach of the current study and also suggests that systems-level solutions are required to facilitate improved school food recovery. In this study, one of the main reported barriers was the increased handling costs incurred through food recovery. Others have suggested providing financial incentives to improve rates of food recovery (Buzby et al., 2014). Alternatively, the food recovery experts interviewed in this study purported that mechanisms to increase the cost of landfilling were necessary to make food recovery cost-effective. In a 2017 study by Pollans et al., U.S. cities were more likely to adopt food scrap recycling programs when they already have per unit-pricing (i.e. pay-as-you-throw pricing schemes) for household landfilled waste disposal in place (Pollans et al., 2017). Unit pricing passes the systems costs of sustainable waste management on to consumers and may provide the required uptick in demand for commercial composting to make food waste hauling affordable for non-profits like schools. Yet, food recovery solutions should be evaluated not only in terms of fiscal cost but also on their net environmental impact. For example, it is important to consider the carbon footprint of increased refrigerated transport of donated food and/or hauling wasted food to distant industrial composting and anaerobic digestion sites when selecting the most appropriate food recovery option. The potential for these

unintended consequences of food recovery underscores the EPA's directive to prioritize preventing food waste over food recovery (U.S. Environmental Protection Agency, 2016c). School nutrition programs already have a strong focus on preventing food waste as a means to control program costs (U.S. Department of Agriculture, 2014; National Food Service Management Institute, 2012), and research suggests their rates of pre-consumer food waste are low (Prescott et al., 2019). Yet, food waste is an unintended consequence of food service, underscoring the importance of food recovery alternatives to use when waste is unavoidable.

This study has important limitations to consider. Only pre-consumer waste and recovered post-consumer waste was measured. Landfilled post-consumer waste was not tracked. It is also possible that kitchen staff may have changed their waste disposal-related behavior since they were being observed. The study sample, while representative of Northern Colorado, may not be generalizable to other regions, particularly in terms of available food recovery options. These limitations notwithstanding, this study is the first of its kind to assess food recovery rates, barriers, and facilitators in school nutrition programs, addressing an important gap in the literature.

5. Conclusions and implications

This mixed methods study used a systems approach to examine school nutrition program food recovery. Landfills were the dominant food waste management strategy. Food recovery was hindered by a variety of systems-level factors, such as liability concerns, higher recovery expenses relative to landfilling, inconsistent wasted food volumes impacting the external demand for recovered food, and policy confusion. Interviewees also viewed priorities to promote food safety and quality of recovered food as constraining rates of food recovery. Interviewees viewed share tables and donation of packaged foods prior to school breaks as the most feasible food recovery options. These study findings also suggest that school nutrition staff need professional development on permitted food recovery activities and may need assistance promoting share table use to students, parents and the school community. Landfilling post-consumer waste is a missed opportunity to engage youth in food recovery and promote a cultural shift towards sustainable waste management for future generations. More research is needed on the overall stream of school food waste to better understand the trade-offs between pre- and post-consumer food waste reduction and recovery.

Declaration of Competing Interest

The authors declare that they have no known competing financial

interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

We would like to thank the school nutrition staff and food recovery professionals who volunteered their time and expertise to this project. We would also like to acknowledge Dr. Dawn Thilmany, Professor and Associate Department Head, Department of Agriculture and Resource Economics, Colorado State University, for her advice on the initial conception for this research project. We are also grateful to the undergraduate and graduate Colorado State University students who assisted with the data collection and data entry for this project. This material is based upon work supported by the National Institute of Food and Agriculture, U.S. Department of Agriculture, under award number 2017-67012-28197. Any opinions, findings, or recommendations in this publication are those of the authors and do not necessarily reflect the view of the U.S. Department of Agriculture. Additional funding for this research was provided by the Colorado School of Public Health.

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