**Leso:** Compost-bedded pack barns (CBP) are a relatively new housing system that, compared with FS, appears to improve cow comfort and minimize the risks traditionally associated with conventional bedded-pack barns such as SY … In conventional bedded-pack barns, including SY, cows are provided with an open pack resting area rather than individual stalls. The SY housing system is believed to provide better comfort than FS.

Cows housed in SY also exhibit different behavior than do cows in FS. Fregonesi et al. (2009) found that when offered a choice, cows spend more time in open packs than in equivalent FS … Studies on cows’ time budgets have shown that cows in SY have longer lying times, ruminating times, and synchronization of lying behavior than those in FS (Fregonesi and Leaver, 2001). However, SY may hinder cows’ welfare through increasing the risk of IMI because maintaining adequate cow cleanliness can be a major issue in SY. Cows in SY have been found to be dirtier than those in FS (Fregonesi and Leaver, 2001) and thus to have poorer udder health. In fact, Fregonesi and Leaver (2001) found that both SCC and incidence of clinical mastitis are significantly higher in SY than in FS. Peeler et al. (2000) reported that housing lactating cows in SY is a significant risk factor associated with the incidence of clinical mastitis.

**Leso defines CBP:** Similarly to SY, in CBP, cows are provided with an open bedded pack area for resting and exercise rather than the individual stalls and concrete alleys in FS systems. However, in CBP, unlike conventional SY, the entire pack is cultivated 1 to 3 times per day, and the area per cow required is generally higher than that in other housing systems. Although cow excreta are mixed into the bedding, thus potentially increasing the risk of poor cow hygiene, properly managed CBP can provide a health-promoting, dry, and comfortable surface on which cows can lie, stand, and walk. Because the animals can walk freely within the barn, the term “freewalk housing” has been used to describe this system

In Italy, CBP appeared in 2006 as retrofits of SY barns (Leso et al., 2013), whereas the first specially designed CBP were not built until 2013–2014

In addition, deep straw bedding in SY is known to increase the risk of mastitis (Peeler et al., 2000) and the prevalence of dirty cows (Fregonesi and Leaver, 2001). Nevertheless, in recent years, some Dutch producers have begun to use straw in CBP as an alternative to compost and have found encouraging results. Galama et al. (2014) reported that cows housed in CBP bedded with straw have very low SCC. Regardless of the type of bedding, frequent pack cultivation and a larger area per cow appear to promote better udder health in CBP than in conventional deep bedding systems such as SY (Barberg et al., 2007b)

***Barberg 2007 performance and welfare define bedded pack***

Bedded Pack. The pack (resting) area was typically bedded with dry fine wood shavings or sawdust. The bedding material was aerated to a depth of 18 to 24 twice daily while cows were away at the parlor, most often using a modified cultivator on a skid loader or small tractor … Typically, a semitruck load of fresh dry sawdust (ap-proximately 14 metric tons) was added every 2 to 5 wk, varying by season, weather conditions and cow density. Some dairies preferred to add a smaller amount of saw-dust more frequently, such as once weekly. Typically no bedding material was removed from the pack area during the year, except in fall and spring. The bedded pack area was cleaned out entirely once annually in September or October. A load of clean sawdust was added after removal of the soiled bedding to provide a bedding layer 30 to 45 cm high to start the new pack. By the end of summer, most packs averaged 120 cm high. Several farms removed a portion of the pack mate-rial in the spring to provide space for bedding accumulation during the summer. The soiled bedding was spread on the fields according to the farm manure management plan. Two producers piled the spent bedded material to produce finished compost …

It appears that the practice of aerating the pack to help dry the surface and incorporate manure into the pack might help achieve better udder health in a compost dairy barn than in a conventional bedded pack.

COMPOST DAIRY BARNS IN MINNESOTA: A DESCRIPTIVE STUDY A. E. Barberg 2007a; all 12 twelve barns used wood shavings/sawdust, cultivated twice a day

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***Astiz et al. (2014)***

Astiz, S., F. Sebastian, O. Fargas, M. Fernández, and E. Calvet. 2014. Enhanced udder health and milk yield of dairy cattle on compost bedding systems during the dry period: A comparative study. Liv-est. Sci. 159:161–164

**Dry cows; compares compost bedding to straw yard**

**Defines “compost bedding;”** It typically consists of a large bedded pack area with a basis of straw, sawdust or wood shavings as primary material. On this basis, the manure of the cows arrives daily. After reaching a depth of the bedding mixture of 30–40 cm, the bedding material is aerated daily by using a soil cultivator. This triggers the aeration and the refrigeration of the bedding on the surface, reducing the humidity, turning it into a fresh (one main objective for farms with heat stress seasons) and comfortable resting surface.

Compost-bedded systems; CB systems consist of a primary bedding of barley straw (0.5 kg/m2 ) and a layer of 5 cm deep sawdust. After 18–20 days with animals on this bedding, and after reaching 35–40 cm bedding depth, the compost bedded pack is ready and manure is aerated once a day with a rotary hoe dispositive for the tractor. This cultivator turns over the manure at a depth of 10–15 cm. Afterwards, barley straw is added once a week at a rate of 0.5 kg/m2 . The second group of cows “straw bedding system” (S-Group; n¼181) was also allocated in a loose housing barn with barley straw bedding. The dimensions of this barn were 2543 m2 , with 1162 m2 of roofed surface and 117 feeding places at the feeding alley. This bedding consisted of clean straw (0.5 kg/m2 ), applied on a layer of 5 cm of sawdust; fresh straw was added daily

*Doesn’t give a good idea of thickness of straw bed*

***Fregonesi and Leaver, 2001***

Fregonesi, J. A., and J. D. Leaver. 2001. Behaviour, performance and health indicators of welfare for dairy cows housed in strawyard or cubicle systems. Livest. Prod. Sci. 68:205–216

cows were significantly cleaner in the cubicle system (freestall) but there were no significant differences between systems in milk production, cell count or locomotion score

Milk yields were significantly lower in the strawyard than in the cubicle system due to a significantly higher incidence of clinical mastitis. Cell-counts were significantly lower and cows were significantly cleaner in cubicles

cowshed housing, in which cows are tied by the neck for prolonged periods during the winter months, has been replaced by strawyards and cubicles (leaver 1999) the two systems provide loose housing for dairy cows, but differ in the proportion of bedded area, the depth of the bedding and the formality of lying arrangements

In strawyards, the bedding was long wheat straw given daily, and in cubicles chopped wheat straw given thrice weekly in appropriate amounts to keep bed surfaces clean. The amounts of chopped wheat straw used as bedding in the strawyards and cubicles, respectively, in experiment I were 7.3 and 1.3 kg/cow/day and in experiment II 7.6 and 1.0 kg/cow/day.

Discussion in this paper: “The higher incidence of mastitis in strawyards in experiment II was probably a result of the layout of the yard; which meant that the bedded area adjacent to the concrete area used for feeding was much walked upon. This led to difficulty in keeping clean, that area of the bed, and maintaining cleanliness in the cows”

**This doesn’t do a great job of defining straw yard, and giving an idea of the depth of it; it also is a comparison of straw yards and freestall housing (as we would see it in the US), NOT tiestall housing (and omg tiestalls are called cowsheds in the UK?)**

*From Leso (I think they’re kind of mis-using this citation here):*

“In addition, deep straw bedding in SY is known to increase … the prevalence of dirty cows (Fregonesi and Leaver, 2001)” – *this was comparing stalls with straw to loose laying area with straw; without giving much idea of depth*

***Peeler et al. (2000)***

Peeler, E. J., M. J. Green, J. L. Fitzpatrick, K. L. Morgan, and L. E. Green. 2000. Risk factors associated with clinical mastitis in low somatic cell count British dairy herds. J. Dairy Sci. 83:2464–2472.

The incidence increased when farmers reported that they had straw yard housing for milking cows (compared with cubicle housing) [cubicles== freestall?!]

No definition or description of what a straw yard is in this paper

***Leso et al., 2013,***

Leso, L., M. Uberti, W. Morshed, and M. Barbari. 2013. A survey of Italian compost dairy barns. J. Agric. Eng. XLIV(e17):120–124

Compost-bedded pack barns, generally known as compost dairy barns, are an alternative loose housing system that appears to offer excellent comfort level for dairy cows. In this type of barn, cows are provided with a large bedded area for resting rather than individual stalls. Compost bedded pack refers to a mixture of feces and urine pro-duced by the cows and organic bedding. Unlike conventional straw-bedded yards, the whole surface of compost packs is cultivated once or twice daily to dry the surface and incorporate manure into the pack (Klaas and Bjerg, 2011).

By analyzing interna-tional literature two main types of compost-bedded pack barns could be identified. Although both two types seem to be based on the evapora-tion of water from the pack, management practices, type of bedding materials and barn’s characteristics are significantly different(Galama 2011; Klaas and Bjerg, 2011).The first type, which was initially developed in the USA and applied with some modifications also in the Netherlands and Austria, is based on the development of heat in the pack. In this type of compost barns the most important issue is to maintain adequate chemical and phys-ical characteristics into the substrate in order to promote aerobicmicrobial activity (Black et al., 2013). The most commonly used bedding materials are sawdust, wood shavings and wood chips.

The second type of compost barn takes advantage from the natural drying potential of the air rather than heat production into the pack (Galama, 2011). This type of housing system has been developed in Israel and is receiving an increasing interest in the Netherl ands.

***Galama et al. (2014)***

Galama, P. J. 2014. On farm development of bedded pack dairy barns in the Netherlands. Report 707. Wageningen UR Livestock Re-search, Lelystad, the Netherlands

Not literature, some sort of extension presentation; one farm uses wood chips, the other 2 use organic waste compost

***Ward et al., 2002***

Ward, W. R., J. W. Hughes, W. B. Faull, P. J. Sutherland, and J. E. Sutherst. 2002. Observational study of temperature, moisture, pH and bacteria in straw bedding, and faecal consistency, cleanliness and mastitis in cows in four dairy herds. Vet. Rec. 151:199–206

Looks at different characteristics of the straw bedding between 4 different farms; all straw yards; but doesn’t define them

***(Klaas and Bjerg, 2011***

Klaas I.C., Bjerg B. 2011. Compost barns - an alternative housing sys-tem for dairy cows? CAB Reviews: P rospectives in Agriculture,Veterinary Science, Nutrition and Natural Resouces. 45(6):1-9.

Just describes what a CBP is

***BEST I CAN DO FOR DEFINITION OF A STRAW YARD:***

The strawyard (SY) treatment provided 12.6 m2 /cow with a total area of 4.8 m2 /cow of the same concrete flooring topped with rubber mats found in the FS housing and a total lying area of 7.5 m2 /cow. The lying area was bedded with straw at a depth of 20−25 cm, with daily cleaning and addition of straw to the bedding area to maintain bedding cleanliness and depth

Another paper mentions all bedding removed every five weeks for a “straw yard” treatment

*The effect of free-stall versus strawyard housing and access to pasture on dairy cow locomotor activity and time budget Elise Shepleya, \*, Joop Lensinkb , Hélène Lerusteb , Elsa Vasseura*

While we did not define “straw yards” in our paper, the modern “traditional” or “deep bedded pack” being implemented as winter housing in pasture-based systems in the Northeastern U.S. contrasts to the traditional straw yard, where clean out is often recommended on at least a monthly interval. Bedded packs are primarily used in conjunction with herds that graze dairy cattle from May-November, and material accumulates over the 6–8-month period where they are housed before they are cleaned out once a year. This is in contrast to straw yard systems, which have been used for confinement housing cattle year-round. Straw yards have a long tradition of use in the dairy industry, and as such it is hard to narrowly define what one is- however, a thorough description is provided in XXX, which is overall in agreement with how the authors perceive this housing system: “The strawyard (SY) treatment provided … concrete flooring topped with rubber mats … The lying area was bedded with straw at a depth of 20−25 cm, with daily cleaning and addition of straw to the bedding area to maintain bedding cleanliness and depth.” (Shepley 2020).

***Ofner-Schröck et al. (2015)***

Ofner-Schröck, E., M. Zähner, G. Huber, K. Guldimann, T. Guggenberger, and J. Gasteiner. 2015. Compost barns for dairy cows—Aspects of animal welfare. Open J. Anim. Sci. 5:124–131. https://doi .org/10.4236/ojas.2015.52015. (this seems like a sketchy publication; from Austria)

A compost barn is used mainly as a two-area system with a bedded lying area and a solid feeding alley. Sawdust or dry fine wood shavings or wood chips are mostly used as bedding material, which has to be stirred twice a day. Stirring aerates and mixes faeces and urine into the bedding material, the mixture decomposes by means of aerobic microorganisms.

A compost barn is used mainly as a two-area system with a bedded lying area and a feeding alley, which can have either a solid or a slatted floor. Regarding bedding, good experience has been gained in Austria with sawdust and wood shavings. Starting with a bed approximately 20 to 25 cm high (1.8 - 2.5 m3/animal), about 0.4 to 1.3 m3/animal is added every 2 to 7 weeks (10 - 15 m3/animal and year). The bedding material is loosened once or twice a day with a grubber or rotary hoe to a depth of 20 to 25 cm, working in any faeces and urine. This lets air into the bedding so that the mixture can decompose with the help of aerobic micro-organisms [[6](https://www.scirp.org/journal/paperinformation?paperid=55276#ref6)] . The result is a loose, friable bedding material. Its temperature should be between 30˚C and 45˚C in order to quickly convert the organic substance and kill off undesirable germs while supporting beneficial germs [[7](https://www.scirp.org/journal/paperinformation?paperid=55276#ref7)] . As far as possible, new bedding should not be started during the winter months because it is difficult for the rotting process to begin in the cold. The lying area may be separated from the feeding alley by walls or it may be placed about 30 to 50 cm lower. Compost removal (mucking out) is performed twice a year (in spring and autumn) when the compost bedding has reached a thickness of 50 to 60 cm.

Looked at 138 cows on five different compost farms; literally can’t tell where they pulled data for “cubicle farms”; possibly compares hygiene between compost and cubicles?

*Maybe* finds “the cleanliness of the animals in compost barns is comparable with other housing systems” but there’s no statistics shared here at all

Straw yard descriptions; references from 100 years of housing paper

*Although BP easily accom-modate different breeds and double as manure storage, they require intensive management and large amounts of bedding relative to tiestall or freestall housing to be effective (Bickert and Light, 1982; Thurgood et al., 2009; Benson, 2012)*

*The reduced capital cost to build a BP compared with a freestall barn can make them an attractive option (Kammel, 2005)*

*Providing 10 m2 per cow instead of 9 m2 per cow im-proved lying time (Fregonesi and Leaver, 2002; Kammel, 2005; Fregonesi et al., 2009), increased SCC (Fregonesi and Leaver, 2001), and increased clinical mastitis inci-dence (Fregonesi and Leaver, 2001). Bedded-pack barns may lead to improved cow health and welfare compared with other housing systems.*

***Bickert and Light, 1982***

Bickert, W. G., and R. G. Light. 1982. Housing systems. J. Dairy Sci. 65:502–508

Nothing really helpful in here

***Kammel, 2005***

Kammel, D. W. 2005. Design and maintenance of a bedded pen (pack) housing system. University of Wisconsin Extension, Madison.

***Thurgood et al., 2009***

Thurgood, J. M., C. M. Comer, D. J. Flaherty, and M. Kiraly. 2009. Bedded pack management system case study. Pages 184–188 in Proc. 5th National Small Farm Conference, Springfield, IL. Ac-cessed Aug. 31, 2017. <http://conferences.illinois.edu/resources/20033/Proceedings_8-12-13.pdf>.

*A bedded pack management system (BPMS) is defined here as a covered barnyard and feeding area that holds a variety of dairy cattle, storing their manure through the accumulation of an unturned bedding of dry material for later use as a nutrient amendment*

*The farmer was to add layers of straw bedding as needed to allow the animals to stay clean and comfortable*

*The large amounts of bedding required by the BPMS indicate that limiting the use of the facility to half of the year during inclement months, then keeping animals on pasture, is necessary to make bedding costs manageable.*

*Organic farms that place a higher value on compost, due to the relatively high cost of organic fertilizers and their increased emphasis on soil health, will be better able to justify the additional cost of bedding material*

*Another option to reduce bedding costs would be to design the BPMS to include a concrete feed alley, thereby reducing the amount of manure deposited on the pack*

***Benson, 2012***

Benson, A. F. 2012. Consider deep pack barns for cow comfort and ma-nure management. Cornell University, Ithaca, NY, Accessed Febru-ary 17, 2014

Defines a: deep bedded pack (DBP) system

Benefits:

* *Manure storage*
* *Cow comfort*
* *can be especially helpful to smaller grazing farms*
* *A DBP system generally consists of a foundation of concrete or hard clay. There may be a layer of gravel and then a bedding pack of straw, hay, sawdust or well-chipped wood shavings. Manure and urine mix into the bedding that remains in place for several months and is generally cleaned out once a year.*
* *A deep pack system is different than a composting pack that is aerated in the barn daily by tiller or turning. Biologic activity taking place 5-7 inches deep in the pack provides the heat that cows enjoy through the winter months.*
* *As with any type of housing structure, adequate bedding and good milking hygiene help manage the pathogens naturally found in a bedded pack system. The biggest complaint of owners of DBPs is the cost of the bedding material. This would be compounded on an organic dairy where it is required to use certified bedding.*
* *Cow hygiene at milking is extremely important with cows housed on bedded pack, so cow washing and teat prep practices may have to be upgraded. This is due to the high bacteria count in the bedding*
* *Pack manure mixed with extra carbon is a better soil nutrient then raw manure from typical manure storage.*
* *Particularly adapted to grazing dairies since barns are used only 6 months and allow plenty of time to clean*

*The bedding pack rises over time as more and more bedding is added throughout the winter*

*Allen (2007)*

Book

Fregonesi, J. A., and J. D. Leaver. 2001. Behaviour, performance and health indicators of welfare for dairy cows housed in strawyard or cubicle systems. Livest. Prod. Sci. 68:205–216.

(increased clinical mastitis incidence, increasing amount of laying space from 10m sq from 9 m sq)

Fregonesi, J. A., and J. D. Leaver. 2002. Influence of space allowance and milk yield level on behaviour, performance and health of dairy cows housed in strawyard and cubicle systems. Livest. Prod. Sci. 78:245–257.

Fregonesi, J. A., M. A. G. von Keyserlingk, and D. M. Weary. 2009. Cow preference and usage of free stalls compared with an open pack area. J. Dairy Sci. 92:5497–5502.

***The Dairyland Initiative > Housing Module > Adult Cow Housing > Bedded Pack: Bedded Packs***

*There are currently two contrasting methods to managing a bedded pack barn: anaerobic fermentation and aerobic decomposition.*

*Anaerobic fermentation – Traditional bedded packs*

*Fresh dry straw is added daily to a bed which accumulates in layers over a period of 4 to 6 weeks before removal and replacement. The layers compact, become moist and decompose, removing oxygen from the bed, leading to an anaerobic fermentation. Deep beds of other organic bedding material such as sawdust are very difficult to manage from a bacterial growth standpoint, and such material is better put to use in composting systems. Sufficient bedding must be added to keep animals clean and dry. Sand bedded areas have been used by some farms successfully, where wet contaminated sand is removed daily and fresh sand added weekly.*

*For traditional bedded packs with anaerobic fermentation, straw or similar organic bedding is added to the bedded area daily at a rate of approximately 25 lbs (11.3 kg) of bedding per cow per day. After a period of 4 to 6 weeks, the whole bed is removed and the process is repeated. A bedding retainer in this type of barn should be a 10 inch (25 cm) high, 8 inch (20 cm) wide concrete curb that is rounded at the edges. Such a retainer allows access to the bed along its length, thereby reducing the damage done to the bedded area by cow movement.*

*Aerobic decomposition – Compost barns*

*Deep bedded packs using fine dry wood sawdust are composted by stirring twice a day to a depth of 8 to 12 inches (20 to 30 cm), with the aim of generating a minimum temperature of 140 °F (60 °C), sufficient to inactivate bacterial pathogens, weed seeds, and fly larvae. Moisture levels must be maintained between 40 and 65%.*

***Compost barns*** *are managed very differently than traditional bedded packs since they typically utilize dry fine wood sawdust or shavings as a bedding material. The fine particles are necessary to improve mixing and aeration. Straw, cornstalks, and green or wet shavings are not recommended. Initially, 12 to 18 inches (31 to 46 cm) of dry fine wood shavings are placed on the floor. Fresh bedding is added at intervals dependent on weather conditions, stocking rates, and cow hygiene scores. Most importantly, the bed is aerated at least twice daily. Producers utilize a cultivator mounted on a skid-steer or a tractor-mounted rototiller to stir the bed to a depth of 8 to 12 inches (20 to 31 cm). Cultivation incorporates manure and urine below the surface and aerates the pack, which speeds up microbial breakdown and composting. There is some debate as to whether the pack truly achieves temperatures of greater than 140 °F (60 °C). To date, available data suggests the average temperature is 108 °F (42 degrees °C), meaning the bedding material is only partially composted.*

*The bed may be removed once or twice per year (spring and fall or fall only), depending on the availability of land and the building design. To operate this type of bedded pack, the sidewalls must be solid and at least 4 feet high (1.2 m). Thus, bedded area access in this type of barn must be limited to at least two points, but traffic damage to the bedded area in these locations is a problem. In larger barns, access to the resting area needs to be located at 120- to 160-foot intervals (36.6 to 48.8 m). The loss of approximately 200 square feet (18.6 sq m) of bedded area adjacent to each opening must be considered when calculating bedded space per cow. To prevent cows from walking over the wall adjacent to the feed alley after the pack has built up over time, a fence is recommended along the top of the wall.*

Our farms:

**Stony pond:**

* Shavings/sawdust
* Cultivated 2x day (aerobic composting)
* Cows not fed on pack (YES concrete feed alley)
* Bed only dug out and removed once a year, during the summer months when primarily housed on pasture
* 15 loads of 120 cubic yards shavings/year; 1800 cubic yards wood shavings/year (pack is available to cows year-round)

**Donegan:**

* Shavings/sawdust
* Cultivated 2x day (aerobic composting)
* Cows YES fed on pack (no concrete feed alley)
* Bed only dug out and removed once a year, during the summer months when primarily housed on pasture
* 120 cubic yards of wood shavings every ten days (during 8 months cows are housed on pack)

**Choiniere:**

* Bedded with straw and woodchips
* Cultivated every 48 hrs (?aerobic status?)
* Cows YES fed on pack (no concrete feed alley)
* Bed only dug out and removed once a year, during the summer months when primarily housed on pasture
* 5 yards of woodchips, 1500 pounds of hay every 48 hours

**Butterworks:**

* bedded mainly with straw, adding woodchips as needed
* did not cultivate the pack at all (anaerobic)
* Cows YES fed on pack (no concrete feed alley)
* Bed only dug out and removed once a year, during the summer months when primarily housed on pasture
* 800 pounds dry round bales/day; woodchips: (~7 yds), cover barn with whole load as needed

**Swallowdale:**

* bedded mainly with straw, adding woodchips as needed
* did not cultivate the pack at all (anaerobic)
* Cows not fed on pack (YES concrete feed alley)
* Bed only dug out and removed once a year, during the summer months when primarily housed on pasture
* 3,000 pounds hay per day added, every other month adding some sawdust 2.5 cubic yards

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Notes about grouping different kinds of BP:

While bedded pack systems are not common for housing lactating cows in Vermont (Andrews et al., 2021), farms using a bedded pack system in Vermont are using both compost bedded-packs managed with daily cultivation, and conventional, untilled deep bedded pack systems. The relatively small number of bedded packs being used in our state to house lactating dairy cattle created a challenge for enrolling ten herds using this kind of system in our observational study. As untilled and cultivated bedded pack systems differ in numerous regards (Leso et al., 2020), ideally we would have been able to enroll enough farms using each type and treat them as separate groups in the analysis. Due to the limited sample size available using these systems in the state, it was necessary to combine both types of system in order to achieve our objective of describing udder hygiene, milk quality, and udder health on these loose-housing systems deeply-bedded with organic material in the state. While we acknowledge that grouping them together is not ideal, this diversity is a reflection of how the target population (small-medium, pasture-based organic dairy farms) are actually using this system in the Northeastern U.S. (Benson, 2012). Despite this limitation, by including bedded pack farms managed in a variety of ways, our aim was that the current work sheds light on a broader spectrum of options used within this loose-housing system. Our current study shows that farms can achieve excellent milk quality using either an untilled, deep bedded pack system or an aerobically composting bedded pack system for indoor housing.

Due to the limited sample size available using bedded packs in the state to house lactating dairy cattle, it was necessary to combine both untilled and cultivated bedded pack systems in order to achieve our objective of describing udder hygiene, milk quality, and udder health on these loose-housing systems deeply-bedded with organic material in the state.

created a challenge for enrolling ten herds using this kind of system in our observational study. As untilled and cultivated bedded pack systems differ in numerous regards (Leso et al., 2020), ideally we would have been able to enroll enough farms using each type and treat them as separate groups in the analysis. Due to the limited sample size available using these systems in the state, it was necessary to combine both untilled and cultivated bedded pack systems in order to achieve our objective of describing udder hygiene, milk quality, and udder health on these loose-housing systems deeply-bedded with organic material in the state. While we acknowledge that grouping them together is not ideal, this diversity is a reflection of how the target population (small-medium, pasture-based organic dairy farms) are actually using this system in the Northeastern U.S. (Benson, 2012). Despite this limitation, by including bedded pack farms managed in a variety of ways, our aim was that the current work sheds light on a broader spectrum of options used within this loose-housing system. Our current study shows that farms can achieve excellent milk quality using either an untilled, deep bedded pack system or an aerobically composting bedded pack system for indoor housing.

Thank you for this comment, and agree that it should be more overtly addressed in the manuscript. We recognize that for this manuscript, the “bedded pack” group represents both farms using a deep bedded pack or “conventional bedded packs” and “compost bedded-packs,” as defined in Bewley et. al (2017). The smaller than anticipated number of dairy farms using bedded packs for housing lactating dairy cattle in our state created a challenge for enrolling ten herds in our observational study, and we recognize this as a limitation (lines 759-763).

Although there is a diversity of management styles under this umbrella term, these systems do still share some important things in common: both are enclosed, loose-housing facilities deeply bedded with organic material, in which bedding and waste accumulate throughout the 6–8-month period of time when cows are housed on it and which is only removed once a year. Both systems use carbon-rich substrates on which urine and manure are not removed when bedding material is renewed, which is in contrast to other housing systems. In both types of bedded packs, cows urinate and defecate on the same surface used for laying, and cows’ teats are exposed to bacteria from manure and the organic bedding which acts as a growth medium. Both systems address the desire to provide a loose-housing option where the initial investment of the building is more readily affordable for those with outdated facilities, provide cows with a large, comfortable laying area which allows them to move freely, allows for improved foot and leg health, and allows farms to avoid the need to store and spread large amounts of liquid manure. Both systems provide dairies with a valuable source of compost as a nutrient amendment, through the accumulation of waste and bedding material in the pack, and both are perceived to integrate well into pasture-based farm systems.

Recent previous work has primarily focused on describing bedded packs that are actively managed for aerobic composting (Leso et al., 2020). Leso et al. contrasted composting bedded packs managed with daily cultivation with conventional static bedded packs, such as straw yards, noting the reduced cow cleanliness and increased risk of mastitis associated with the latter. While we did not define “straw yards” in our paper, the modern “traditional” or “deep bedded pack” being implemented as winter housing in pasture-based systems in the Northeastern U.S. contrasts to the traditional straw yard, where clean out is often recommended on at least a monthly interval. Bedded packs are primarily used in conjunction with herds that graze dairy cattle from May-November, and material accumulates over the 6–8-month period where they are housed before they are cleaned out once a year. This is in contrast to straw yard systems, which have been used for confinement housing cattle year-round. Straw yards have a long tradition of use in the dairy industry, and as such it is hard to narrowly define what one is. However, a thorough description is provided in Shepley et al. (2020), which is overall in agreement with how the authors perceive this housing system: “The strawyard (SY) treatment provided … concrete flooring topped with rubber mats. … The lying area was bedded with straw at a depth of 20−25 cm, with daily cleaning and addition of straw to the bedding area to maintain bedding cleanliness and depth.” (Shepley 2020).

While there exists a substantial body of recent work exploring udder health on compost bedded-pack systems, we were unable to find much peer-reviewed literature describing udder health on deep bedded pack systems (in contrast to the large volume of work on udder health in straw yards). While bedded pack systems are not common for housing lactating cows in Vermont, both composting and static systems are used (Andrews et al., 2021). In service to starting to establish a body of work describing udder health on bedded packs used on organic dairies in Vermont, the current work attempts to shed light on a broader spectrum of options used within this loose-housing system. Our current study shows that farms can achieve excellent milk quality using either an untilled, deep bedded pack system or an aerobically composting bedded pack system for indoor housing.

*Notes from meeting with Sandra, and language to add to Discussion after meeting with her*

For BTSCC and newSCS, bedded packs performed slightly better than the other two facility types; however, the relatively large standard errors for newly-elevated SCS makes it difficult to rule out biologically important effects of facility type on this metric.

For BTSCC, BP were numerically lower than the other two facility types; however, the difference in BTSCC from BP for both FS and TS only equated to an increase of about 1.5 cells/mL, which does not amount to an important difference at the bulk tank level.

NewSCS was also numerically lowest for BP, at 2.3% lower than FS and more modestly at 0.43% lower than TS. Ruegg et al. propose a benchmark of having <8% of cows developing a new subclinical mastitis infections per month, whereas Schukken et al. (2011) suggest <10%. Using either of these figures, a difference of 2.3% between facility types would be substantial. However, the relatively large standard errors for both estimates of newSCS makes it difficult to interpret the effect of facility type on this metric.

BP had numerically lower chronSCS in comparison to FS (1.5%), but were equivalent to TS herds in this respect. As an industry benchmark is to have <10% of cows with chronic subclinical mastitis infections carrying over month to month (Minnesota Extension), the numeric difference seen between BP and FS for this outcome may be biologically important. Standard errors for both estimates were relatively large for chronSCS estimates, making it difficult to interpret the effect of facility type on this outcome.

ElevSCS was numerically lowest for TS herds, while FS herds had a higher proportion of cows with an SCS ≥ 4.0 on current test compared to BP farms. The relative magnitude of the difference for these estimates when compared to BP may be biologically significant (1.8% for FS, -2.4% for TS), as a suggested goal for herds is to have a <15% prevalence for cows with subclinical mastitis (Ruegg, 2011). Again, the large standard errors for both estimates of elevSCS make it difficult to interpret the effect of facility type on this metric.

With regards to numeric difference in avg. SCS, BP farms performed slightly better than FS, and were equivalent to TS. The increase in estimated avg. SCS for FS equates to an increase of roughly 16,250 cells/mL at the cow level, which represents a slight to modest increase in SCC. Given the proportionately large standard errors for both estimates, interpretation of the effect of facility type for this metric is challenging.

Cows on BP farms numerically made slightly more milk than those in TS, and were equivalent to those in FS. This increase of 1.7 pounds for BP over TS represents roughly 3% of the average STD 150-day milk production, which is a relatively modest increase in milk production. Regardless, the comparatively large standard errors for both STD 150-day milk estimates make it difficult to interpret the effect of facility type for this metric.

For the two udder hygiene metrics, TS farms had numerically higher proportion of dirty udders and avg. udder hygiene score, while FS and BP systems were equivalent. Interpretation of these numerical differences is challenging though, given that the standard errors for all four estimates are large relative to the coefficient estimates.

For BTSCC, BP were numerically lower than the other two facility types; however, the difference in BTSCC from BP for both FS and TS only equated to an increase of about 1.5 cells/mL, which does not amount to an important difference at the bulk tank level.

NewSCS was also numerically lowest for BP, at 2.3% lower than FS and more modestly at 0.43% lower than TS. Ruegg et al. propose a benchmark of having <8% of cows developing a new subclinical mastitis infections per month, whereas Schukken et al. (2011) suggest <10%. Using either of these figures, a difference of 2.3% between facility types would be substantial.

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ElevSCS was numerically lowest for TS herds, while FS herds had a higher proportion of cows with an SCS ≥ 4.0 on current test compared to BP farms. The relative magnitude of the difference for these estimates when compared to BP may be biologically significant (1.8% for FS, -2.4% for TS), as a suggested goal for herds is to have a <15% prevalence for cows with subclinical mastitis (Ruegg, 2011).

With regards to numeric difference in avg. SCS, BP farms performed slightly better than FS, and were equivalent to TS. The increase in estimated avg. SCS for FS equates to an increase of roughly 16,250 cells/mL at the cow level, which represents a slight to modest increase in SCC.

Cows on BP farms numerically made slightly more milk than those in TS, and were equivalent to those in FS. This increase of 1.7 pounds for BP over TS represents roughly 3% of the average STD 150-day milk production, which is a relatively modest increase in milk production.

Although some numeric differences for outcomes were observed between facility types for newSCS, chronSCS, elevSCS, avg. LS, and STD 150-day milk, given the proportionately large standard errors for all estimates, interpretation of the effect of facility type for these outcomes is challenging.

For the two udder hygiene metrics, TS farms had numerically higher proportion of dirty udders and avg. udder hygiene score, while FS and BP systems were equivalent. However, interpretation of these numerical differences is difficult, given that the standard errors for all four estimates are large relative to the coefficient estimates.

With the exception of elevSCS when compared to TS, five of the six udder health and production metrics and both udder hygiene measures for BP were either numerically better or equivalent in comparison to the most commonly-used facility types for organic dairy cows in Vermont. This may potentially indicate a biologically important difference. AS there was no statistical difference, this would seem to suggest that this housing type is a viable option for housing lactating dairy cattle in Vermont. However… standard errors… small sample sizes… therefore, larger studies in the future…

For five of the six studied udder health and production metrics, and both udder hygiene measures, numerically BP either performed slightly better or were equivalent in comparison to the most commonly-used facility types for organic dairy cows in Vermont. However, there were relatively large standard errors for some of these estimates, making it difficult to rule out biologically important effects of facility type for these metrics. This is likely a result of the small group size for each facility type, and future studies enrolling larger number of farms using each type of housing are needed to more definitively explore these relationships.

***Notes from meeting with Sandra 3.25.24:***

*General advice:*

\_ Making their suggested edits; try to accommodate all of the ones that you reasonably *can;* if you can take their suggestions maybe 2/3 or ¾ of the time. Buys you some good will to maybe say no to a few things

\_ If you can’t or really don’t want to make a change they suggest, and you can justify why, it’s okay to say no to a few things

\_ At the beginning, put in a blurb saying *“thank you for your careful reading and all the suggestions you’ve made; the process of incorporating the suggested changes has certainly improved this work and made this a stronger manuscript”*

\_ Just in general, be accommodating. Also, it’s okay to reach out directly to the editor if two reviewers are suggesting polar opposite things, or you really feel strongly you don’t want to make a suggested change

*Re: linear regression for proportions:*

\_ Theoretically, yes, it is a bounded outcome (0, 1) but not really in the classic sense

\_ Might make sense if we were looking at outcome on a per-cow level, but these are herd-level estimates. Maybe, if you wanted to estimate the number of cows going from no IMI -> IMI the next month for one herd, may make sense to do logistic regression

\_Ask UVM statistician?

\_Cite 1 or 2 other JDS papers where it was treated as a continuous outcome (other researchers took a similar approach)

\_We appreciate this comment, but… there are other examples of previously-published work in JDS…

\_May make sense with a more limited number of levels for the outcome- BUT, theoretically unlimited number of decimal points between 0-100 for percent cows with a certain udder health outcome at one time

*Reviewer 1, power statements*

\_ Look at the estimate effects for all the models of the outcomes; were all outcomes pointing in the same direction (was it always a benefit that cows were housed on bedded packs)? How big are the estimate effects (and their standard errors)?

\_ If not a consistent pattern, may see some low, some high, some sitting in the middle… OR maybe the estimate is close to zero (they are equivalent)

\_ This may help show the “biological importance” of the findings; acknowledge the limitations of the study (small sample size/group size), and “future studies should be undertaken which…”

\_ “With the exception of X outcome, five of the six outcomes for BP were either numerically better or equivalent to the other housing types, potentially indicating a biologically important difference.”

New infections: This proportion should generally be less than 10%

From ruegg 2011:

<15% cows with somatic cell counts <200,000 (prevalence)

<5-8% of cows developing new subclinical mastitis infections per month(incidence)

From Minnesota benchmarking website:

<10% chronic cows

University of Minnesota Extension Dairy Team. Using DHIA Records to Benchmark Herd SCC. Accessed Apr. 1, 2024. <https://qualitycounts.umn.edu/sites/qualitycounts.umn.edu/files/2022-01/w-mp-5.pdf>

University of Wisconsin-Madison, School of Veterinary Medicine. The Dairyland Initiative: Housing Module, Adult Cow Housing, Bedded Pack. Accessed March 20, 2024. https://thedairylandinitiative.vetmed.wisc.edu/home/housing-module/adult-cow-housing/bedded-pack

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Things left to do:

* ~~Address the merging of the different kinds of BP~~
* ~~Acknowledge this in abstract~~
* ~~Shorten the Discussion section~~
* ~~Pull back on “conclusiveness”~~
* ~~The depth of bedding issue~~
* ~~Random comments: modelling count data, modelling proportions~~

Thank you for this comment, and we appreciate the suggestion. We have taken this recommendation into consideration, and consulted with a few other epidemiologists who agree that using a linear regression for modelling these outcomes (percent newly-elevated SCS, percent chronically-elevated SCS, percent of cows with SCS ≤4) is an acceptable method of analysis. Although it is true that conceptually the prevalence of these three udder health measures is bounded by 0-100%, there are theoretically an unlimited number of decimal points between 0 and 100 that these values could take. These are herd-level values, taken from DHIA records, for one particular point in time relative to our farm visits. If we were looking to estimate the likelihood of one cow in a herd becoming a case for a new intramammary infection from one test to the next, we agree that a logistic regression would be the appropriate analysis. Although we appreciate this comment, we would like to point out there are other examples of previously-published work in JDS and other peer-reviewed journals using this approach for the same kind of herd-level udder health data:

Patel, K., S. M. Godden, E. Royster, B. A. Crooker, J. Timmerman, and L. Fox. 2019. Relationships among bedding materials, bedding bacteria counts, udder hygiene, milk quality, and udder health in US dairy herds. J. Dairy Sci. 102(11):10213-10234.

In the above study, linear regression was used to model *“the proportion of cows with an intramammary infection (IMI), where infection was defined as LS ≥4.0; the proportion of cows with a new IMI, where new IMI was defined as LS changing from <4.0 to ≥4.0 in the last 2 tests; the proportion of cows with a chronic infection, where chronic was defined as LS ≥4.0 on the last 2 tests…”*

Dufour, S., Dohoo, I.R., Barkema, H.W., Descôteaux, L., Devries, T.J., Reyher, K.K., Roy, J.-P., Scholl, D.T., 2012. Manageable risk factors associated with the lactational incidence, elimination, and prevalence of Staphylococcus aureus intramammary infections in dairy cows. Journal of Dairy Science 95, 1283–1300.

In the above study, linear regression was used to model herd prevalence: *“The relative effect of herd incidence and elimination rates on the herd prevalence of IMI was assessed. For this purpose, a linear regression model was used. The dependent variable was the quarter prevalence of Staph. aureus IMI in the herd over the 2 yr of the study, and explanatory variables were the herd incidence and elimination rates during that same period.”*

Lobeck, K.M., Endres, M.I., Shane, E.M., Godden, S.M., Fetrow, J., 2011. Animal welfare in cross-ventilated, compost-bedded pack, and naturally ventilated dairy barns in the upper Midwest. Journal of Dairy Science 94, 5469–5479.

In the above work, *“A linear mixed model (MIXED procedure, SAS Institute Inc.) was built to evaluate the association between housing system and the outcome variables: lameness prevalence, hock lesion prevalence, BCS, hygiene score, CCI, SUI, mortality rate, turnover rate, respiration rates, and mastitis infection prevalence,”* where “mastitis infection prevalence” was defined as “c*alculated by the number of animals with a test SCC >200,000 cells/mL divided by the total number of animals in the pen.”*

Eckelkamp, E. A., J. L. Taraba, K. A. Akers, R. J. Harmon, and J. M. Bewley. 2016a. Sand bedded freestall and compost bedded pack effects on cow hygiene, locomotion, and mastitis indicators. Livestock Science 190:48-57.

The above work used “*The MIXED procedure of SAS … to develop all models for all barn type comparison analyses…High SCC prevalence and RCMI explanatory variables were barn type, maximum ambient THI period, mean herd hygiene score, and all 2-way interactions. High SCC prevalence and RCMI were calculated as a herd percentage for each visit period. High SCC prevalence was the % of the herd with a DHI SCC ≥200,000cells/mL at each visit period.”*

***------- John’s language around defining bedded pack comment from reviewer 1***

AU: *let’s give that a shot*… Thank you. We recognize that the term bedded pack and composted bedded pack are vague because they appear to have variable use in the literature and lay-publications. Here we adopt the definition of Leso et al. (2020) *blah blah blah* and have revise the sentence for clarity. We have deleted the sentence at line 106 (*maybe*) to avoid redundancy. Reviewer x also noted the potential nomenclature issues….

it is used we have revise this sentence to include information to help define this Bedded packs are a broad category reference and describe the various things we observe … Here we define bedded pack systems as…. We distinguish them from simple traditional straw yards by the following factors…. Reference